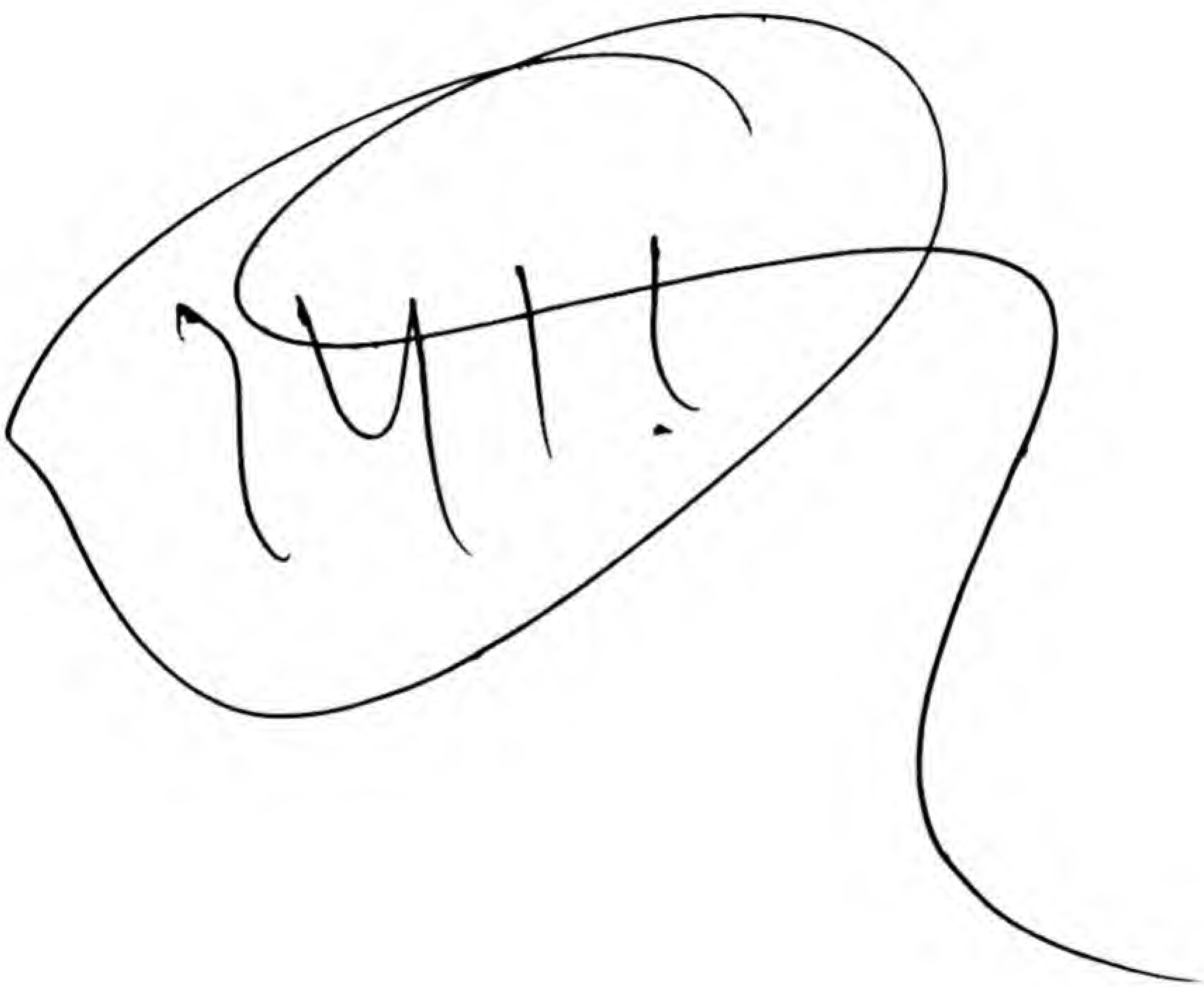
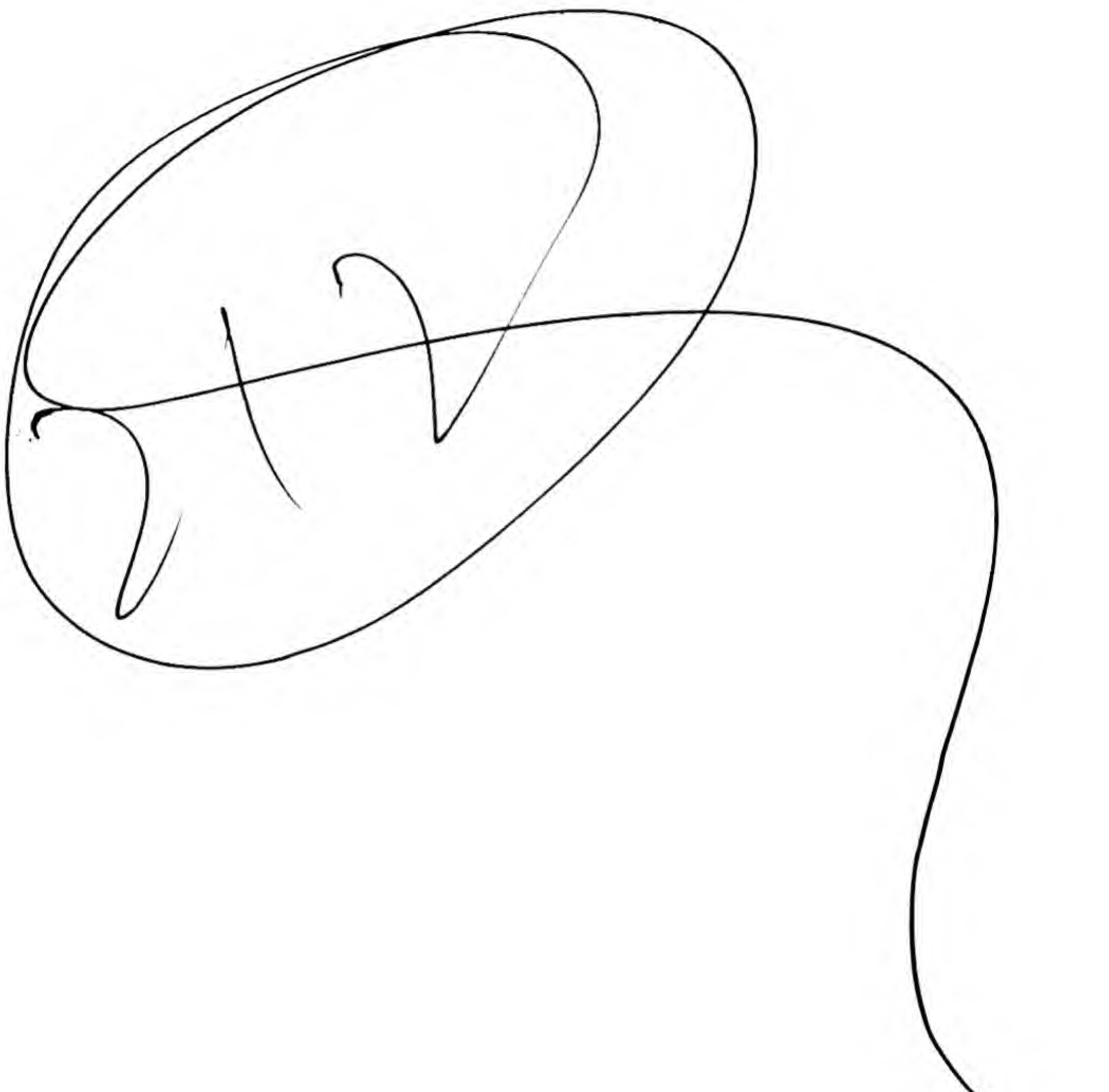
917

912



TIME AND MOTION STUDY

AND FORMULAS FOR WAGE INCENTIVES



TIME AND MOTION STUDY

AND FORMULAS FOR WAGE INCENTIVES

BY

STEWART M. LOWRY, B.S. IN I.E., M.E
Director of Industrial Relations, Procter and Gamble Company, Cincinnati

HAROLD B. MAYNARD, M.E.
President, Methods Engineering Council, Pittsburgh

G. J. STEGEMERTEN
Staff Supervisor, Time Study and Methods, Westinghouse Electric & Manufacturing Company, East Pittsburgh

THIRD EDITION

McGRAW-HILL BOOK COMPANY
NEW YORK AND LONDON
1940

PRINTED IN THE UNITED STATES OF AMERICA

26 27 28 - MP - 9

PREFACE

There is a growing realization throughout industry that one of the greatest opportunities for cost reduction lies in the improvement of existing production methods. The improvements do not necessarily have to be obtained by the installation of new and costly mechanical equipment; improvements of important magnitude can often be secured merely by analyzing the process and operations carefully, eliminating unnecessary work and motions, and installing simple, practical, work-reducing methods. Experience has shown that with sufficient study any operation can be improved, and this applies to operations which have already been subjected to study as well as to new or unstudied operations. The percentage of industrial operations existing at the present time which could not profitably be subjected to detailed methods study is very small.

Therefore, in this, the third edition of "Time and Motion Study and Formulas for Wage Incentives," the material relating to the study of methods has been greatly expanded. It has been demonstrated that greater methods improvements will result if the study is undertaken systematically than if improvement is sought merely by correcting the inefficiencies which first impress themselves upon the attention of the observer. In view of this, considerable care has been taken to develop the description of the methods-study technique in its proper chronological sequence.

In recent years, there has been a shift of emphasis from time study to methods study. This is quite proper, for, as has been pointed out, the improvement of methods is highly important. At the same time, the place and importance of correctly measuring the time factor after the method has been improved should not be overlooked. Good methods are desirable under any industrial conditions, but good methods coupled with the establishing of equitable production standards give far better results than good methods alone. Unless some means is established of maintaining a good method in effect after it has been devised, it is likely to change gradually, and the change is almost always in the direction of decreasing effectiveness. A time standard can be

a valuable aid in maintaining a good method. Unless the established method or one equally good is followed, the job cannot be done within the standard time. This focuses the attention of both the management and the worker on the job and forces the reestablishment of the proper method. Therefore, the establishing of a time standard tends to peg the method at a point that is at least as good as when the standard was set. This in itself is an important reason for combining methods study and time study. The added value of time standards in connection with wage incentives is, of course, universally recognized.

There is an increased interest on the part of labor in the conditions under which it works. The authors have long recognized that labor has a right to be informed on the subject of time and motion study, and that this work should be done with the interests and problems of labor in mind. The time-study procedure described in this book was designed originally to produce understandable studies, studies which could be checked and interpreted by the worker himself should he wish to go into the matter. Every revision in the procedure has been made with the idea of increasing its accuracy and understandableness. All the procedures described herein are in successful everyday use throughout representative sections of industry.

As time and motion study has developed, it has reached out and embraced certain other procedures which it did not formerly consider, notably operator training and wage-incentive administration. The complete procedure is known today as "methods engineering," and those who administer it are known as "methods engineers." There is little real difference, if any, between the methods engineer and the time-study man who does his work in accordance with the aims expressed on the first page of Chap. II. The term "time-study man," however, is still in wider use than the term "methods engineer," and therefore, it is retained in the present revision of the book. It should be understood, however, that the authors consider the two terms as interchangeable.

The leveling procedure devised by the authors and first described in the original edition of the book has answered a definite need by providing a fair way of adjusting time-study data to a standard level regardless of the skill and effort of the operator on whom the data were secured. It has, therefore, been widely used. In a few cases where difficulties have been encountered in applying the leveling procedure, it has been found that they were

largely due to a misunderstanding of the procedure and its limitations. It is hoped that the revised description will make it clear that the leveling procedure is not designed to adjust for differences in method; rather it adjusts only for differences in skill, effort, and certain working conditions within a limited range. The definitions of the degrees of skill and effort as recognized by the time-study man have been revised in an attempt to make them clearer to all readers, and the discussion of the leveling procedure has been somewhat amplified.

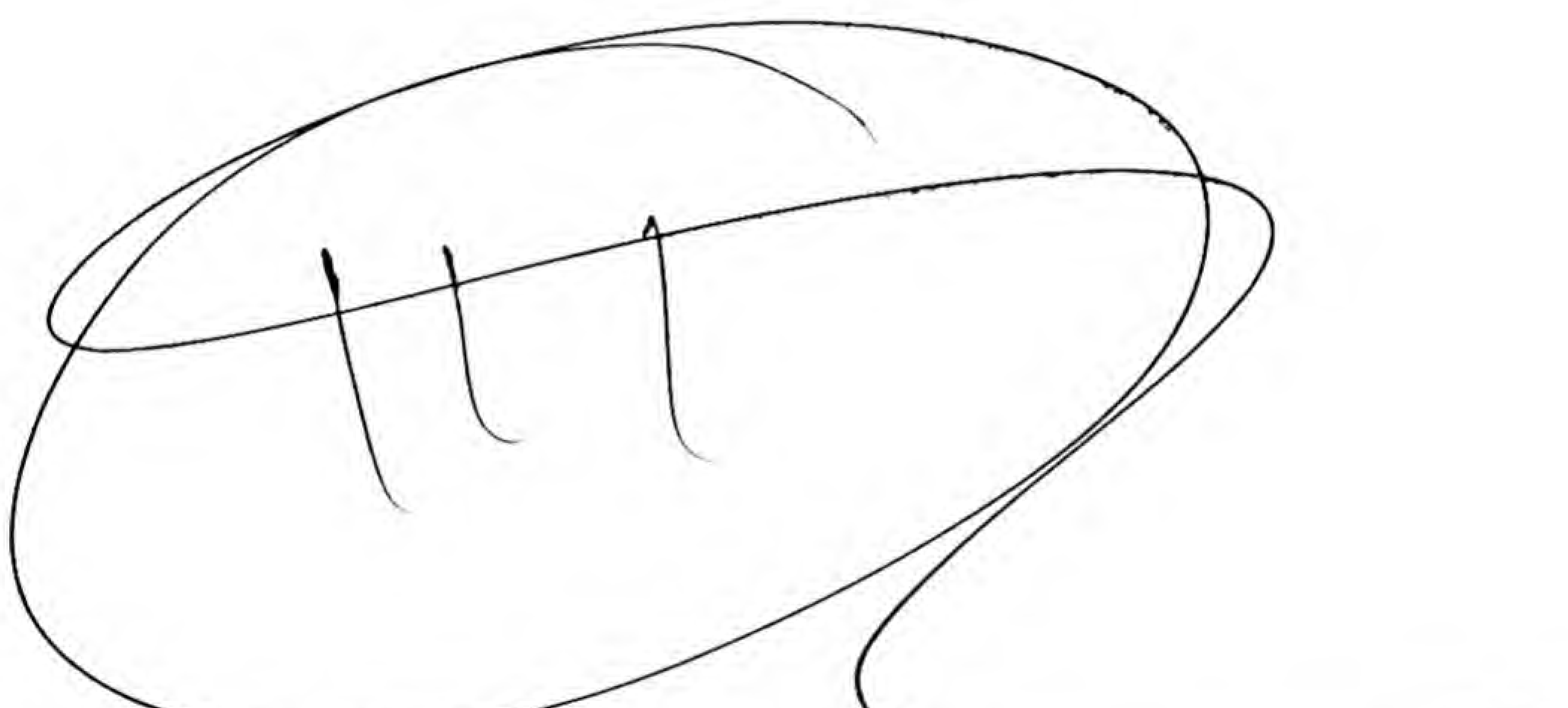
Due to the expansion of the methods-study material, it has been necessary to omit some of the formula examples and descriptions of wage-payment subjects previously included. It is particularly hoped that the omission of the formula examples will not give rise to the impression that the application of formulas is in any way limited to the classes of work covered by the examples which have been retained. Formulas have been applied successfully to nearly every line of industrial endeavor and have been invaluable wherever it has been necessary to establish a large number of standards on a varied class of work.

The authors would like to repeat the acknowledgments made in previous editions to the Westinghouse Electric & Manufacturing Company, Dean Dexter S. Kimball and Professor John Bangs of Cornell University, Allan H. Mogenson, and Dr. Lillian M. Gilbreth. Acknowledgment is also made to Lawrence B. Grella and Robert O. Boden of the Methods Engineering Council, the Bell & Howell Company, and the Detroit Stamping Company for their valuable assistance in connection with the preparation of the present edition. Appreciation is expressed also for the friendly comments and criticisms on the book made by industrial engineers, industrial psychologists, and educators throughout the world.

THE AUTHORS.

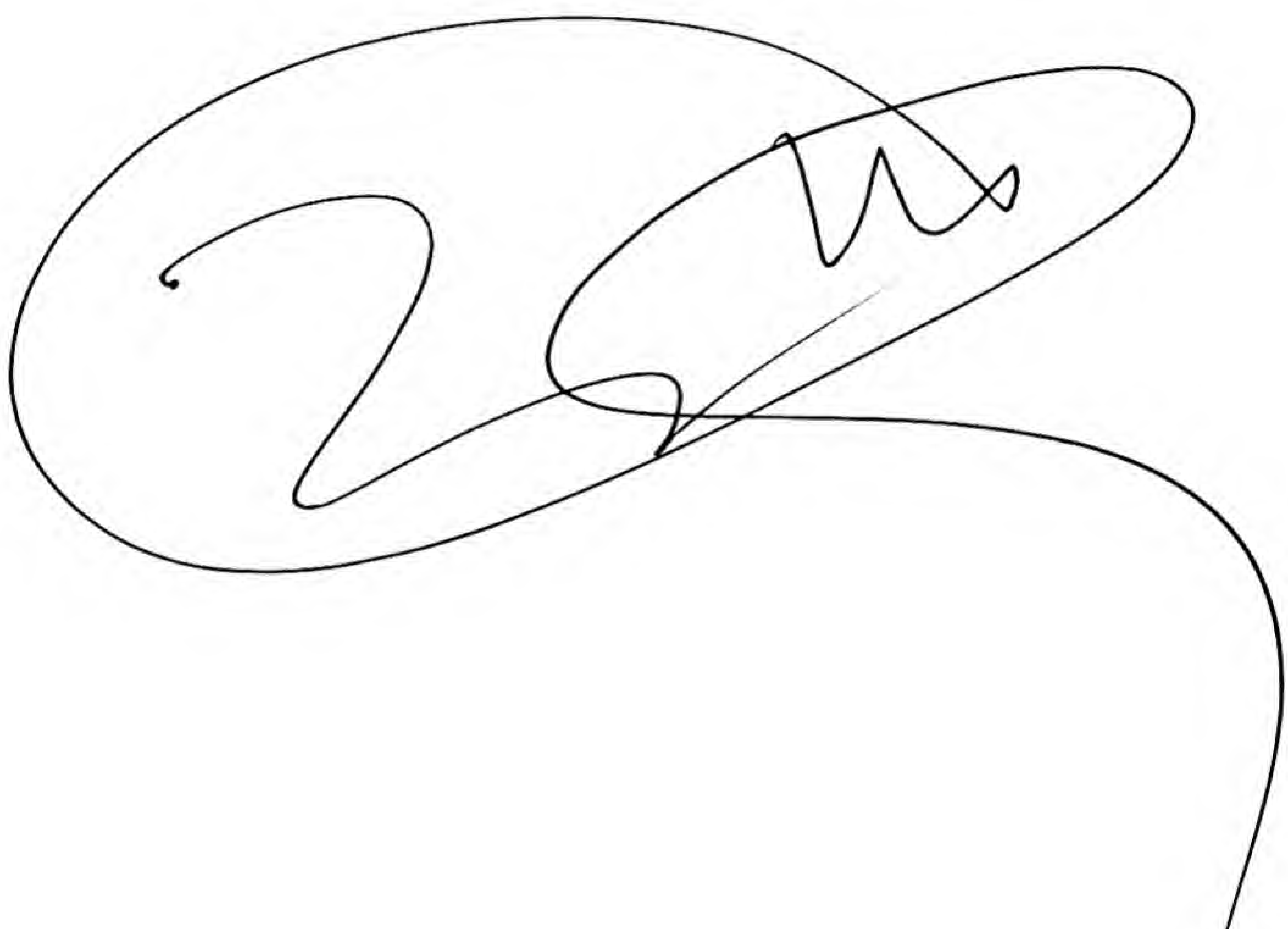
October, 1940.

CONTENTS



PART I

TIME AND MOTION STUDY



CHAPTER I

ECONOMIC NECESSITY FOR MEASUREMENT OF LABOR

Primitive man existed at first, independent of his neighbor, fashioning his own weapons, hunting his own food, and making his own rude clothing. As time went on, however, certain individuals became experts in making weapons, others in hunting game, and still others in making clothes. Here is recognized the beginning of the division of labor and of the various trades. One man made weapons for all his neighbors, another hunted food for the immediate community and so on, each trading the products of his labor beyond his own requirements for a portion of his neighbors' excess. This trading in commodities is known as bartering, which along with other economic factors, such as mediums of exchange and credit, is the foundation of the vast commercial activities of today.

Labor—the Commodity.—Bartering involves only the physical exchange of goods. When it became inconvenient and cumbersome actually to exchange goods for goods, mediums of exchange were developed. It then became possible to express the respective values of all commodities in commonly accepted and convenient units of measure. Beads and other such trinkets are recorded as being among the first things used in a manner similar to that in which gold and silver are used today.

Trading in commodities by means of a medium of exchange is known as buying and selling. The primitive specialist, previously referred to, who devoted his entire time to one activity, found it profitable to sell his surplus production beyond his own requirements and, with the medium of exchange thus secured, to buy other things that he needed. If he met with success, his work increased until he soon reached the limits of his personal output. In order that his business might grow, he soon found it necessary to employ help. He then became a buyer of labor just as he already was a buyer of commodities other than

those which he made. In fact, labor has frequently been classed as a commodity. Whether it is or is not strictly a commodity may be debatable, but the fact that it possesses economic value cannot be disputed.

Measurement of Labor.—Commodities or anything else of value are purchased by measure; that is, a certain quantity or number of units of a certain quality is obtained for the price paid. The units of measure vary. For instance, coal is measured by the ton or bushel, cloth by the yard, land by the acre, and brick by the thousand.

It was logical, then, that a measure should be developed for labor, and also that the units should be changed as they were found to be inadequate or unfair, just as present methods of fixing commodity values have grown from the original crude and incorrect attempts.

Slave labor was not uncommon in times past. For this, the purchaser had to pay only the market value of the slave or perhaps finance an expedition of conquest into enemy territory for the purpose of bringing back captive slaves. He then became the owner of a potential supply of labor to use as he saw fit during the lifetime of the slave. Serfs exchanged their labor for a place to live which was granted them by their feudal lords.

Under the apprenticeship system, young men, or rather their parents, contracted to sell their labor over a period of years in exchange for a working knowledge of a trade. The demand for labor increased with industrial development, and men learned to market their labor by the year, month, day, and hour. The last named is a method which is still widely employed. It is a safe estimate that there is more labor purchased today on a straight hourly basis than in any other way. This, of course includes not only productive labor, but all indirect, maintenance, and expense labor. The tendency, however, is away from this method toward fairer and more equitable plans.

Quality of Labor.—It has been said previously that commodity values are determined by quality as well as quantity or measure. Thus far, the value of labor has been discussed only from a quantitative viewpoint, the measure being on the basis of time. But it must not be overlooked that quality enters into the determination of labor values just as it does into the determination of commodity values. The statement that the hourly basis of wage

payment is, in general, unfair and unsatisfactory may bring forth the argument that quality is taken into account because different classes of labor demanding different degrees of skill and experience are purchased at different hourly rates. The hourly rate of tool makers as a class, for instance, is higher than that of ordinary machinists, and the rate of cabinet makers higher than that of carpenters. This is true, but the element of quality has been only partly taken into account. Although tool makers as a class are worth more than machinists as a class, it does not necessarily follow that all tool makers or all machinists are of equal value.

Quality of labor is determined by the personal characteristics of the worker including such things as skill, effort, intelligence, experience, physical strength, endurance, and ingenuity.

Value of Labor.—Quantity alone is not an adequate measure of the value of labor. Assume that two mechanics are each given 100 small metal parts to be laid out for drilling. The two jobs are identical and both men have equally good tools and equipment with which to work. One man proceeds to lay out each individual piece by means of his scales, calipers, scribers, center punch, hammer, and other layout tools. Each piece requires approximately 3 minutes or the operator takes 300 minutes or 5 hours to complete his 100 pieces. The other man spends 1 hour in making a template to fit the work. Holes are properly located so that it is only necessary to lay the template over each piece, insert a center punch in the proper holes, tap it with a hammer, and the piece is accurately laid out. The whole operation for each piece takes only about 30 seconds, or a total of 50 minutes is needed for the entire 100 pieces. The second man thus requires only 50 minutes plus the 1 hour for making the template or less than 2 hours to do the same amount of work which the first man took 5 hours to accomplish. It is evident that the second mechanic is of considerably more value to his employer than the first simply because his labor possesses an element of greater quality. Why should an employer be obliged to pay for the additional 3 hours required by the workman who did not use his head when 2 hours is sufficient to complete the job?

On the other hand, neither can quality stand alone as a measure of the value of labor. Two men may be equally capable of turning out work of high quality, but one may produce in larger quantities than the other over the same period of time, thus making himself of more value to his employer than the other.

Therefore, the judicious employer does not want to purchase merely labor, which is measured only on the basis of time as when he buys it by the hour. He wants to purchase output or useful work which, in this discussion, will be regarded as the results of labor that has been applied toward a desired accomplishment. From an economic standpoint, he is not particularly interested in the amount of labor required to produce each unit. He is more vitally interested in producing as many units as his facilities permit, assuming, of course, that the market will absorb his maximum output. It is the product itself that he sells, not the labor used in producing it. The fact that one unit contains more labor than another similar unit does not make the first one of any more value to the consumer nor will it command a higher price. It is the desire of the employer, therefore, to have a uniform labor cost in each unit of product, which is possible only when he purchases output or useful work rather than mere labor.

Compensation.—To pay for work on the basis of results demands some means of fixing the compensation for each unit of output. In order to satisfy this demand, management has been obliged to experiment and grope about in search of a satisfactory answer.

Chapter II treats more fully of these early attempts and failures to supply this need and reviews the difficulties which were encountered in developing what is now recognized as the real solution—scientific time study.

Employees' Objectives.—The employee now recognizes the advantages to himself of working in a shop where modern time-study methods are used.

The principal objectives of the employee are to secure maximum earnings commensurate with the effort expended, while working, in so far as conditions will permit, in a healthful and agreeable environment. Time study has contributed immeasurably toward the attainment of these objectives for the employee, because thorough time-study analysis brings to light the undesirable and improper working conditions and methods and establishes a fair time value for every job. These time values, when used with a proper incentive system of wage payment, enable the employee to increase his earnings by increasing his output.

Employers' Objectives.—The employers' objectives are, briefly, to secure a maximum output of standard quality at a minimum

cost per unit. Progressive employers recognize the proper application of time-study methods as being one of the most important factors in modern industrial management which tends to bring about the accomplishment of their objectives. Such obvious benefits to the employer as having a better-satisfied working force, resulting in a minimum labor turnover, and getting what he pays for are alone sufficient to command his cooperation and support.

Conclusion.—It is now clear that the necessity for measuring human effort was an economic development, which paralleled and was actually a part of our normal industrial growth.

CHAPTER II

AIMS, FUNDAMENTALS, AND DEVELOPMENT OF TIME STUDY

Chapter I has shown the desirable end, paying the worker, not for the time he spends at his place of work, but for what he actually accomplishes. The means to this end—the method used to determine the number of standard hours which will be allowed on any job—is time study.

Aims of Time Study.—If a number of experienced time-study men were asked to define the aims of time study, a few might thoughtlessly say: "To determine the number of standard hours in which an average man could do a given piece of work." The rest, being real time-study men, would say:

> To subject each operation of a given piece of work to a close analysis, in order that every unnecessary operation may be eliminated and in order to determine the quickest and best method of performing each necessary operation; also to standardize equipment, methods, and working conditions; then, and not until then, to determine by scientific measurement the number of standard hours in which an average man can do the job.

Thus, it may be seen that in reality the time-study man is a motion, methods, and time analyst and that time study is really motion, methods, and time study. However, for convenience's sake, the terms time-study man and time study are commonly employed and will be used hereafter throughout the book, but the full meanings of these designations should not be lost sight of.

It is because time study aims to do more than merely set time values that it has gained for itself such an important position in modern management. Because it eliminates waste of time, effort, and material and because it increases output on standard operations and processes used in production work as a result of close study and searching analysis, time-study work is now recognized by every progressive plant manager as a leading factor in the production of a high quality of product at a low cost and in a manner which improves labor relations.

Average Performance.—In order to set equitable time standards for doing any task, it is necessary to establish certain criteria of performance. To this end, a normal reasonable performance called the average performance has been arbitrarily established by definition. It is the performance given by the operator who works with average effort and who possesses average skill as defined in Chaps. XVI and XVII. Under most incentive plans, average performance represents the point of 100 per cent efficiency.

It should be clearly understood that when the time-study man speaks of the average performance in a given occupation, he has in mind not the average of all human beings, or even the average of all persons engaged in that occupation. The average performance is established by definition and not statistically and represents the time-study man's conception of a normal, standard working performance which may reasonably be expected from anyone qualified for the work at hand. If sufficient inducement is offered by incentives or otherwise, this performance may be considerably surpassed.

The performance of any operator represents the end results of a number of factors such as previous experience, natural aptitudes, physical strength, intelligence, and so on. When these factors are measured by the techniques available through the industrial psychologist, and when only those operators who are properly qualified are placed on a given task, the performance level will be raised considerably above the arbitrarily established "average." This concept is one of the most important in time-study work.

Above and below the average performance level lie the other levels commonly encountered in industry. These levels, subdivided into skill and effort, are also established by definition and are known as poor and fair for the levels below average, and good, excellent, and super or excessive for the levels above average. In general, about 15 per cent more is produced by the superskilled worker than by the worker possessing average skill when both are exerting the same effort under the same conditions and when both are following the same method.

In spite of this comparatively small difference in output attributable to skill, cases are frequently encountered in industry where one worker produces twice as much as another. This is due to differences in effort, steadiness of application, and method.

Of the three, effort is the least important, for the difference in output between the man working with average effort and the man exerting excessive effort, all other factors being the same, is only 13 per cent on the average. Large differences in output, therefore, are largely due to variations in the amount of time spent at work, or to method, or to a combination of all factors. Proper operator selection and training, coupled with an equitable wage incentive plan, tend to eliminate large variations in output among industrial workers.

Standardizing the Work.—It is of little use to establish a time value on an operation if the method of performing that operation is to be changed overnight. The operation must be studied, analyzed, and discussed from every angle before the time study is taken. Quite often the task of standardizing the methods of doing a given job will take much longer and will require much more thought than the actual taking of the time study.

Some of the things which must be considered in standardizing work are labor-saving tools, jigs, and fixtures, most efficient cutting speeds and feeds, arrangement of the work bench, material-handling equipment, methods and motions used by the workman in doing the job, and working conditions, such as light, heat, and ventilation. All these will be discussed more fully later.

Changing Established Time Values.—Once a time value has been established on a job, it must never be changed as long as the conditions and methods in effect when the time study was taken still exist. In some cases, it may be permissible to raise a time value if the time-study man has obviously made a mistake in setting it and if the workman is not being allowed time for all the operations which he must perform. But if the error is in the other direction, the value must not be lowered. There is one possible exception to this rule and that is where the high time value is plainly due to a clerical error on the part of the time-study man. The management should not be expected to pay for such mistakes. When the time value is changed, the greatest care should be taken to show the man or men affected that a clerical error and not an error in judgment is being corrected. Correcting an error in judgment after a worker has brought it out by doing the work in much less time than that allowed is absolutely fatal to any incentive plan. Far better that the management stand the expense of a few time values wrongly made too liberal than that the workman lose faith in the fairness of the incentive system and get the

feeling that he must restrict his output to a certain amount if he is not to have the rate reduced. The practice of cutting rates, unfortunately, was quite general in the early days of setting piece rates by guesswork, and there is a feeling in the mind of the workman that he will be allowed to make only a certain amount of money. Only by guaranteeing that a time value once established is permanent unless methods, tools, or design of the part is changed may the management expect to secure from the workman his hearty cooperation and best effort.

When a change in methods, tools, or design does occur, the operations affected by the change should be retimed and the time values changed to suit the new conditions. The change should not be used as an excuse to change unaffected time values which may be a little too high.

Inspection Requirements.—The time-study man, before he makes a time study of a job, must first become familiar with the inspection requirements. He should find out from the inspector just what will be required in regard to finish, fit, dimensions, and the like. By this, the time-study man will know whether an operation is necessary or unnecessary and whether the workman is doing the job poorly or too well; in short, he will be able to prevent the workman from doing too much and thus wasting time and effort, and he will see that the workman is allowed time enough to do all that is necessary. The time-study man, however, does not determine quality.

When studying a job that has already had work done upon it, the time-study man must check the inspection requirements of the previous operation to make sure that the condition of the job is what it should be. This will prevent the man who is being timed from getting a time value for doing or finishing an operation for which allowance has already been made.

Beginnings of Time Study.—The above principles of time study were not always known nor did they just happen. They are the result of a great deal of development work extending over a number of years.

When the idea first occurred of paying a man for what he does, the question at once arose, "How is the management to determine how much a man can do in a given length of time in order that it may know what to pay him?" This was answered by assuming that this amount could be determined best by the man who knew most about the work. The duty of establishing time

values or piece rates was given in most cases to the foreman in charge of the work. It soon developed, however, that these men had little to guide them but judgment and that in many cases their judgment was incorrect. They knew "how" and "why" but not "how long." In addition, the tendency of a human being to be influenced by his own likes and dislikes was noticeably present. One man's opinion of the honesty and ability of another man was a decided factor in the setting of time values. The foreman, in general, considered the setting of time values as secondary in importance to his other work. When a workman approached a foreman whose mind was occupied with production problems to ask for a time value for a job, the value was often given without much thought. Under this system, a great many time values were necessarily very inaccurate. They were either too low to enable the man to earn a fair day's wages or so high that the management felt that earnings were too high and accordingly cut the rate. This led to dissatisfaction and ill feeling on all sides.

The Overall Check.—Out of this chaos of guesswork, a new method arose. In large organizations, a new department was created and in small ones, a new job was born. This department in some plants was known as the rate-setting department and the men in it as limit setters or rate men. These rate men were chosen on the basis of their skill in and knowledge of the work and for their general intelligence, because it was still felt that a man must be an expert at the work to set time values. These rate men differed from the foreman in that their only duty was that of establishing time values.

The rate man, in some cases, estimated the time value for a job to be performed from a drawing of the part. He analyzed the work and determined to the best of his ability, which was by no means constant, what was required and how the job should be done. From the knowledge thus gained, he estimated the time value.

In other cases, he actually watched the job as it was being done and noted the length of time required to do a number of pieces. The time value was established by adding to the average time any allowances which the rate man felt were justified. Under this system, the man could extend the time for doing the work in a number of small ways which the rate man could not readily detect. Then, too, the rate man used himself as the standard when judging others, which was only natural. The inconsist-

encies which resulted were many and serious and led to a great deal of suspicion and mistrust. High earnings were made which were out of proportion to the increase in production. The rate man, seeing this, became suspicious and lost confidence in both the workman and himself and acted accordingly. The workman, as a matter of self-protection, resorted to any means through which he could extend the time of doing the job while being checked. As a matter of principle, he fought every time value set whether it was good, bad, or indifferent.

And all this time, the necessity was growing for a better, fairer, and more accurate method of establishing time values. To this end, time study was developed.

Introduction of Time Study.—Dr. Frederick W. Taylor has many times been referred to as the father of time study. He was responsible for the introduction of the fundamental principles of time study, and it was largely due to his efforts and his faith in his work that time study withstood the criticisms and antagonisms of old-school pessimists and finally won the recognition which it deserved. Scientific time study as it is now known has been developed upon the foundations laid by Dr. Taylor.

The value of time study was not fully recognized at the start and was generally opposed by both employer and employee. The employer did not see how anyone, seemingly unfamiliar with the conditions existing in his shop, could with a stop watch correct the inconsistencies which his foremen with their years of experience had been unable to control. They judged time study from the surface only and did not investigate the underlying principles.

The opposition of the employee was a little more justifiable. For years he had suffered from various attempts at time setting, and he had no reason to believe that the new method would be any better than the old ones had been. The stop watch appeared to him as an inhuman device for reducing him to the status of a machine, and it was no easy task to convince him that time study would work to his own advantage. He was convinced, however, and now, where a group of men have been working under a good incentive system based on time study, it would be very hard, if not impossible, to get them to go back to former methods. They realize that they get fair treatment and justice under the time-study system, and they know that they have the opportunity to

earn all that their abilities will permit without fear of a reduction in time values.

Spread of Time Study.—As time study began to be known, the more progressive employers went more deeply into the subject and soon began to realize its possibilities. They saw that time study would conserve their diminishing labor supply and that it would bring about the training of better workmen. When these employers had used time study for a while, they began to forge ahead of their competitors because of lower costs and greater efficiency. To meet this, the other employers had to fall in line.

The more time study was used, the more uses were found for it. Its application was broadened daily until now there are few jobs which cannot be placed on an incentive basis by the use of time study.

CHAPTER III

QUALIFICATIONS OF A SUCCESSFUL TIME-STUDY MAN

To be a successful time-study man, one must be able to carry out the aims, principles, and practices of time study and to get the desired results with the least amount of friction and discord. In a plant where time study has been long established, this is a comparatively easy task, but where the idea is new to both men and management, there is likely to be a certain amount of resistance and criticism. It requires a high-grade man to handle a situation of this kind successfully, and it will be useful to fix firmly in mind the essential characteristics that such a man must have.

Personality and Tact.—A good personality is necessary for success in nearly any line, and this is markedly so in time-study work. A time-study man must be able to get along with people in a positive way. Many men get along by merely keeping still and giving in, to the point of weakness. This is the negative way. The time-study man must be able to hold his ground when he feels that he is right and to gain his point without losing the cooperation and good will of those opposing him. He must be able to establish new methods with due regard for the feelings of those who originated the old ones. He deals directly with the workman through a most sensitive point of contact—the pay envelope. He will meet with obstacles, yet he must put through that which he believes is right and at the same time make his work pay dividends.

To do all this requires tact, sympathy, and an understanding of the wishes and desires of those with whom he is working. He must have a real interest in his fellow men and be guided by a practical conception of the limitations of human nature.

The time-study man must in addition have no little sales ability. In almost everything he does, he is performing the function of a salesman. He is selling new methods to the shop supervisors and selling time values to the workmen. It should be understood that selling in its true sense does not mean forcing

something on an unwilling customer, but rather showing the customer his need for the thing, creating his desire for it, and then furnishing him with it.

Patience.—A time-study man must possess patience. He should be able to see the fulfillment of his plans delayed, he should be able to talk calmly to those who may have lost their calm, he should be able to experience lack of cooperation and to withstand criticism, all without losing his equilibrium. A time-study man must have the respect of the supervisors and the workmen with whom he deals, and no other single quality will do more toward securing this respect than the ability to keep his emotions under control.

Judgment and Self-confidence.—A time-study man needs better than normal judgment. He must keep his head during a heated discussion in which others are excited and a little irrational, in order that he may be ready to pass calm and impartial judgment on the subject under discussion. He will be called upon frequently to determine the intrinsic worth of new ideas and suggestions. He must be broad-minded and open to conviction, he should be able to view a question from every angle, and he should possess the faculty of basing his conclusions upon the merits of the case rather than upon the influence of preconceived prejudices.

He must also be able to judge men. He must size them up and sense whether or not they are honest with him. If they try to slacken their efforts during a time study, he must realize it and be able to tell the degree of skill that each man possesses. In exercising his judgment, he should strive to be fair-minded and to keep his sense of proportion.

Confidence in himself and his work is essential to a time-study man. New ideas meet with opposition from unprogressive or ultra-conservative men, and unless the time-study man has this confidence, this natural resistance to change is likely to worry him unduly.

Education.—One of the important requirements for a time-study man is that he have at least a high-school education or its equivalent. This equivalent may have been obtained in the shop, at night school, or through correspondence courses. In addition to academic training, the more shop experience a man has the better, for it helps to balance his perspective in a way that can not be accomplished by theory alone. A time-study man

should be grounded in the fundamentals of algebra and English, for without these he cannot hope to derive formulas or to express himself clearly in his instructions and reports. Any other study which provides mental training and teaches one to think and reason for himself will be helpful. The more mathematical training a man has the better, for this will be invaluable in all formula work.

The college man has the advantage of a more thorough academic training, but if he is a recent graduate, he will need some shop experience to give him more of the practical viewpoint. He will need to be able to use shop terms and talk a common language with the workmen in order to gain their respect for his knowledge and ability. For these reasons, it is better to give a college man a few months on the shop floor where he can associate with the workmen as one of them before starting him in on time-study work.

Analytical Ability.—A successful time-study man will have, primarily, an analytical mind. Time-study work requires constant analysis, constant dissecting of systems, methods, and processes, and the viewing of each element separately. The time-study man should be able to go directly to the bottom of every problem and determine the reasons underlying existing conditions. He should have a naturally inquisitive mind and a desire to investigate and learn everything connected with his job.

The time-study man must be alert and always on the lookout for new ideas and improvements. He should have originality and an inventive turn of mind, so that he can work out new and better methods for doing things. He must first recognize the problem and then solve it.

Interest.—To be a success at his work, a man must like it. Since the time-study man's work is largely that of solving problems, he must like to do this. Every unsolved problem should present a challenge. A time-study man is likely to be successful in his work if he is motivated by an interest in what is useful and practical and by a desire for scientific truth.

There are several factors that make those who are properly qualified like time-study work. Work which does not present obstacles is likely to be dull. The time-study man finds two obstacles which he must overcome before he can accomplish results. Most new ideas and improvements, no matter how good, meet with a certain amount of opposition. Most changes are at

CHAPTER IV

ELEMENTS OF TIME STUDY

It has been said previously that time study means considerably more than the mere recording of elapsed time during the performance of a piece of work. It is the intent, in this chapter, to

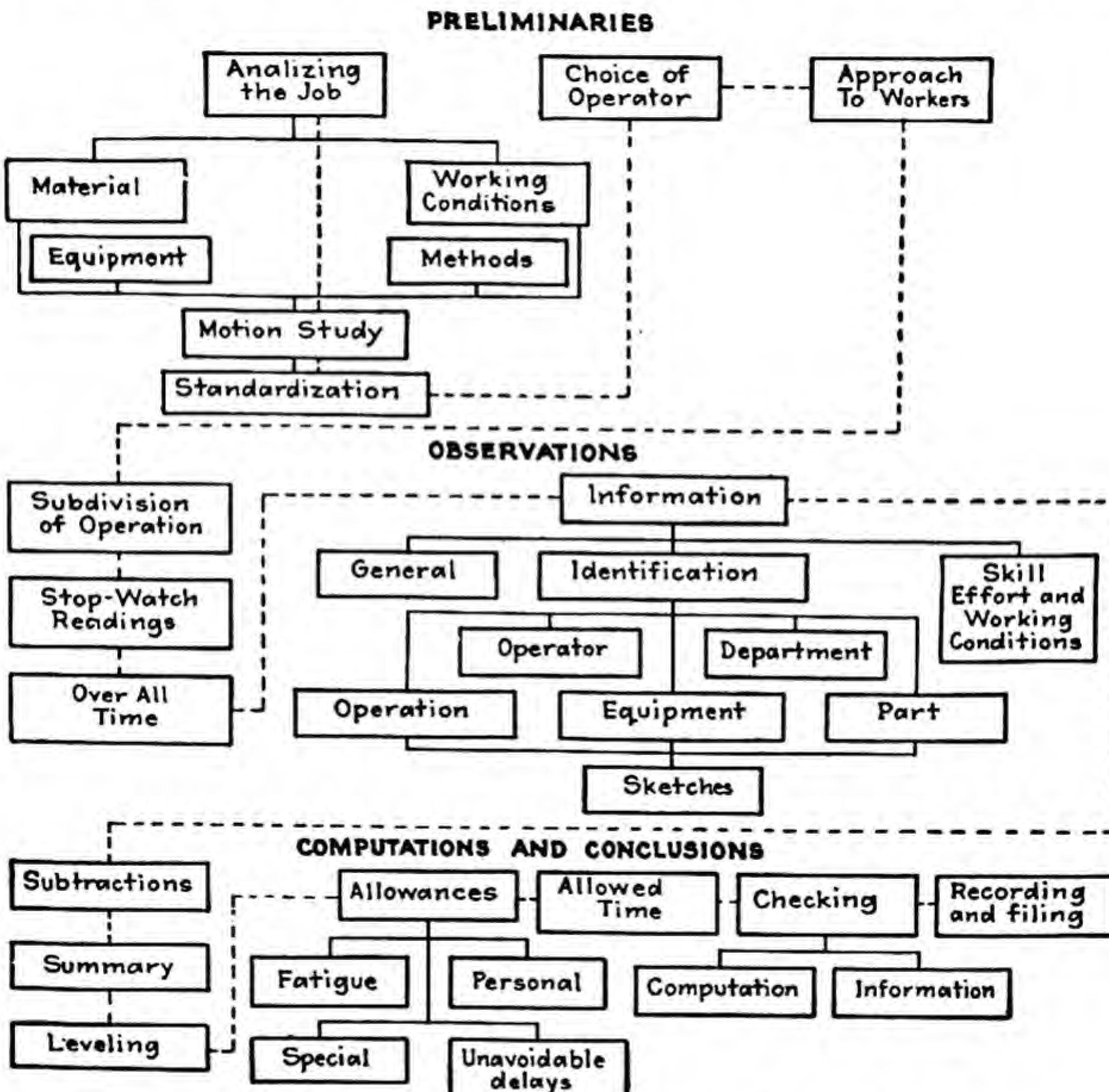


FIG. 1.—Graphic analysis of the elements of time study.

present a composite picture of what is involved, to describe briefly the different steps essential to the making of a good time study, and to show their relation to each other and the order in which each should be considered. In Fig. 1, time-study procedure is

analyzed graphically into its various elements, each of which is treated briefly in this chapter. Each of the more important elements is also given a subsequent chapter devoted exclusively to a full and complete discussion.

Operation Analysis.—The proper consideration of this subject is essential. The analysis of the job is a thorough study of existing conditions, methods, equipment, and anything else that might affect the time to perform the work satisfactorily. The tools which the time-study man uses to assist him in his analysis work consist of process charts and a form known as the analysis sheet. Process charts offer a convenient means of summarizing a number of important and related facts about any process in a form convenient for study. The operations and inspections performed, the distance traveled, the time spent in storage, and other similar data are charted for study on one of the several types of process charts available for the purpose.

Then with a clear understanding of the process as a whole in mind, each step of the process is subjected to a more detailed analysis. Such factors as the purpose of the operation, inspection requirements, material, material-handling methods, and workplace layout and tool equipment are subjected to searching study in the attempt to discover possibilities of bringing about an improvement in methods. Analysis of the job has a decided influence upon the ultimate results. If done properly, it will greatly simplify the work to follow and will facilitate the successful application of the time value which is determined by subsequent time study.

Motion Study.—Motion study is so closely tied up with the analysis of the job that it is difficult to draw a definite line of demarkation between the two. While the time-study man is analyzing the job, he will be giving considerable attention to the motions used in doing the job so that equipment, conditions, and the like will be best suited for doing the job with the minimum number of motions. During the motion study proper, the time-study man will give detailed attention to each minute motion used, in order to reduce the motions necessary and to establish the proper sequence of motions for doing the job in the one best way. This close study may suggest further changes in equipment, tools, and fixtures. If the job is highly repetitive and consists largely of hand motions performed with great rapidity, the motion study may be made with the aid of a motion-picture

camera, so that it may be thoroughly analyzed later by projecting the resulting pictures at a slower than normal speed or by studying the individual pictures separately. If such refinement seems inadvisable, the motion study may be made by observation and stop-watch checks, bearing in mind always the laws of motion economy discussed more fully in the chapters devoted to a discussion of motion study.

Standardization.—All this analysis and study of the factors influencing the performance of the job are made with a view toward standardization, another very important preliminary to the actual time study. It is practically useless to start taking studies or setting time values until the job is standardized. Using a production job as an example, this condition may be defined by saying that the job is not standardized unless each piece is delivered to the operator in the same condition, and it is possible for him to perform his portion of the work on each piece by completing a set cycle of motions by doing a definite amount of work with the same equipment and under uniform working conditions. Once this standardization is effected and found to be workable, the time value is established accordingly, and it is reasonable to expect the operator to do the job within the allowed time by continuing to follow the prescribed method.

Choosing the Operator.—Very often there is only one operator employed on the particular job in which the time-study man is interested. In this case there is no choice, but whenever the time-study man has the opportunity of making a choice where several operators are doing the same work, he should, of course, select the one from whom he can expect the best results. It is of considerable assistance to have the confidence and cooperation of the operator, and an operator who has this attitude towards the time-study man is always a desirable one to study. Intelligence breeds understanding, and understanding of time-study principles by the workman generally commands cooperation. Hence, it is well to study the more intelligent operator. He can be reasoned with and is more likely to receive favorably the time-study man's suggestions to experiment with new methods or ideas. He may make some good suggestions himself. The operator selected should be thoroughly accustomed to the method of doing the work so that he will proceed from one operation or motion to the next without hesitation or delay in an efficient and systematic manner. The operator who likes his work and has a

reputation for doing good work is usually a good choice, for he doubtless has analyzed the job to a certain extent himself.

Other advantages being equal, it is more desirable to make the study on the work of the more skilful operator, not because a minimum performance time is to be secured but because the more highly skilled man is also more consistent and more systematic. His skill is, of course, taken into consideration when the leveling process which will be described later is used. It is not a good policy to study an operator who has an antagonistic attitude toward time study, if it can be avoided. If there is no better choice, an effort should be made to convert the antagonist before proceeding with the study. This is often accomplished by explaining the purposes and fairness of time study.

Ordinarily, judgment is passed on the merits of a worker, in a very general way, by saying that he is above average, average, or below average. This classification conveys some idea of relative ability, but when one stops to analyze what is really meant, he finds that such a description is inadequate because no workman is, or should be, judged on the basis of any single characteristic, but rather on the basis of all the characteristics which influence his ability as an operator. These characteristics are mainly as follows:

Attitude: feeling toward work, fellow workers, and company.

Conduct: attention to work.

Dependability: attendance, punctuality, and reliability.

Intelligence: judgment, resourcefulness, and ease of learning.

Performance: quality and quantity of work, waste, and broken tools.

Physical qualities: physique, health, and strength.

It will be readily appreciated that a worker can be above average, average, or below average in any one of these characteristics, and it is necessary that the time-study man should consider all of these details or as many of them as possible in choosing the operator.

Approach to Worker.—An inexperienced time-study man frequently makes the mistake of antagonizing a worker simply by his method of approach. It is part of a time-study man's job to gain the confidence and good will of the workmen. He cannot be successful in this if he treats them indifferently. They do not appreciate being regarded as a part of the machine which they are operating; yet a time-study man apparently does just

this if he calmly walks up with his watch and begins to record readings without offering any comment or explanation which would tend to create a friendly spirit of mutual interest. It is well to explain to workers who are not accustomed to working under observation the methods and purposes of time study. Often they do not understand that it is of no advantage to them purposely to introduce delays and unnecessary operations. It should be made clear that such things are not included in the allowed time and that they merely complicate the study. Operators generally misinterpret the motives of the time-study man when he selects the skilled man for his study. They are inclined to feel that the allowed time will be based upon that man's performance, thus making it very difficult, if not impossible, for the average man to do the job in the time given. This is, of course, erroneous, and they should be made to understand that the leveling method of determining values enables the time-study man to arrive at the correct time regardless of the speed and the skill with which the operator works.

It is helpful to a time-study man, when determining his method of approach, to try to place himself in the position of the worker and to ask himself what he would expect from a time-study man and how he would like to be treated. There is no excuse for the feeling of suspicion and mistrust that sometimes exists between observer and worker. Human nature, after all, is pretty much the same everywhere, and workers, like everyone else, will generally respond favorably to an open and frank method of dealing with them. Nothing will command their respect and their cooperation more than a realization that the man with whom they are dealing knows his business. In order to create this impression, the time-study man must be able and willing to discuss intelligently the practical, as well as the theoretical, phases of the work. One of the many reasons for proper analysis of the job is here apparent.

Subdivision of Operation.—If a job has been properly analyzed, motion studied, and standardized, the sequence of motions for the one best method will have been determined. The next step is to subdivide the complete operation into a number of smaller operations which will be studied and timed separately. These subdivisions are commonly called elements of the operation or elemental operations and will be referred to as such hereafter, although, strictly speaking, the division is not made into true

elements because each one would be so short that it would be impossible to time it with a stop watch. This step is worthy of close study; it draws upon the knowledge and judgment of the time-study man more than at first might be supposed. He is obliged to define exactly in a few well-chosen words and in a limited space on the time-study form every motion or group of motions and detailed operation performed by the worker. This demands familiarity with technical as well as practical shop terms and a knowledge of the proper application, manipulation, and nomenclature of the machines, tools, and equipment used. The breaking up of the job into its elemental motions must be clean cut and sharply drawn, so that when the watch readings are being recorded, one element will not overlap the next. It is often advisable to make a preparatory line-up of the sequence of motions. Some thought can then be given to the best arrangement on the time-study form so as to be the most economical with space and to facilitate the recording of the watch readings. If the elemental operations are described and lined up properly, one who is familiar with the line of work should be able to visualize every step by merely reading over the list, even though he has not actually seen the particular job performed. The information should be so specific that a competent operator could use it as instructions for doing the job even though he might never have performed the operation before.

Stop-watch Readings.—The recording of watch readings is regarded by many people as the principal feature of a time study. The importance of accuracy at this point is paramount and must not be slighted in the least. Without correct watch readings, all else is useless.

Much of the success of time study depends upon the preparatory steps that have been discussed thus far. They call upon the highest qualifications of the time-study man, qualifications without which he cannot be a good time-study man. Yet here, when one comes to the actual technique of time study, he finds that the principal if not the only major requirement is accuracy. Anyone of normal intelligence who can concentrate can quickly learn to record watch readings; yet he may never be able to qualify as a good time-study man. All that goes before is in preparation for the observations, and all that follows is based upon the data secured at this time. The vital importance of accuracy should now be apparent.

The foregoing must not be construed to mean that the work of taking observations is easy. To stand in one position with attention fixed simultaneously on a stop watch and on the hands of an operator for several hours is a physical strain. It is also a mental strain to concentrate on the job when surrounded by disturbing influences. It is not difficult to acquire the necessary skill to record observations, although this requires practice. Concentration must be developed to the point where it becomes a habit. The principal difficulties encountered are foreign operations, variations in sequence, and a number of successive short operations which make it necessary to remember the readings until the occurrence of an operation of sufficient length to allow time for recording them. Practice will develop the skill needed to meet these irregular situations without affecting the accuracy of the observations.

Overall Time.—The starting and stopping times of the study as shown by the ordinary watch should always be recorded. From this the overall elapsed time for the duration of the time study may be readily computed. It should be equal to the sum of all the detail times, foreign operations, and delays, and when divided by the number of pieces completed, will show the average overall time for each piece. This overall time is valuable as a ready check on performance during the study, but it should not be allowed to influence the determination of the allowed time, because it includes everything that occurs during the course of the study.

The overall time for the study expressed in decimal hours should check roughly with the final watch reading recorded in the body of the study. Thus, a check of the accuracy of the stop watch will be obtained. In addition, the overall time gives the operator something that he himself can check if he so desires. He can note the starting and stopping time of the study on his own watch or the departmental clock, and can check his times against those of the time-study man. Then if he wishes, he can assure himself that every second of the time which elapsed from the moment the study started until it finished has been accounted for in the time study proper, and can thus assure himself that nothing has been overlooked. From the time-study man's viewpoint, the fact that the operator himself can check the results of the time study at least roughly is an important aid in enabling him to demonstrate the correctness of the time value which he establishes.

Information.—A time study, to be of value for future use, must tell the whole story of the job in such a way that it will be understood by anyone familiar with time-study methods other than the observer who might have occasion to refer to it 6 months or a year later. This will not be possible unless all identifying and other pertinent information is recorded at the time the study is made. Provision is made on the back of the sheet for such data. Records should be made to show complete identifications of the operator, the part or piece of apparatus, the machines, tools, and equipment used, the operation, and the department in which the operation was performed. Sketches, for which space is provided, are generally a desirable and satisfactory adjunct to verbal descriptions. Note should be made of the effort given and the skill exhibited by the operator, of working conditions, and of anything that is peculiar or relevant to the job.

Subtractions.—This step in time-study procedure is just what its name implies. If the continuous method of recording watch readings was used when the observations were made, it is only necessary to subtract successive readings to determine elapsed times. This is simply clerical routine and may often be delegated to a clerk who can be depended upon for accuracy and who understands how to take care of foreign operations, variations in sequence, and other irregularities in the recorded observation. If the snap-back method of reading the watch is used, no subtractions need be made.

Summary of Elapsed Times.—After abnormal values have been discarded, the results of the subtractions—the detail time values—are summarized in an ordinary manner at the bottom of the sheet in preparation for the determination of standard detail values. A detailed explanation of the methods of making a summary is given in Chap. XVIII.

Leveling.—It is now necessary to select or derive the proper time value for each detail motion or operation in the study. This must be done from the summaries which have been made. When it is considered that the detail values often vary over a fairly wide range, sometimes as much as 100 per cent for short operations, it will be appreciated that this task must be approached with careful thought and sound judgment. At this stage, skill, effort, and working conditions must be taken into account. Obviously, no general rule can be laid down which can be applied in all cases. The human element becomes a dominant factor at this point because no two operators are consistently, if ever, of exactly equal

ability. If all workers available for time study were average—no experts and no dullards—the problem would be greatly simplified. It must be remembered that time-study work is subordinate and an aid to the main business of production and must never be an obstruction. It must not require the creation of special or unnatural conditions but rather must be flexible enough to fit in with the general scheme of modern industry. The time-study system must be applicable to all operators, good, bad, or indifferent. The work must go on whether the most desirable type of operator is to be found or not. There must be, however, a leveling process at some stage of the work. The time-study man must be able to arrive at a proper time value no matter whether the subject of his observations is a good or a mediocre operator. The time required by a poor operator must be graded down, and the time required by a skilled operator graded up so that the final result is a reasonable allowance such that it can be met by a worker giving average performance. The skilled man will, of course, benefit by his greater production, and the untrained operator will be unable at first to meet the allowed time.

Much has been written and said about proper methods of determining standard time. Some authorities advocate simple averages, others offer methods based upon consistency and length of operation, and still others merely advise the use of judgment. Simple averages are unsound because they do not take into account skill and effort. Consistency and length of operation combined indicate a little more research and theory but are not reliable because an expert operator can fake consistency to the point of deceiving an experienced observer. Broadly speaking, judgment is too general and indefinite and, unless guided, has too wide a range to be relied upon. Guided judgment, however, must play an important, if indirect, part in leveling.

Allowances.—Since the derived time values are net elapsed times, they do not provide for delays and other legitimate allowances. Something, therefore, must be added to take care of such things as fatigue, personal needs, delays outside of the control of the workers, and special or abnormal conditions of the job. Some of these allowances, such as those for fatigue, vary according to the nature of the work, and flat percentages must be determined for each general class of work, such as bench work, machine tool operations, hard physical labor, and so on. The

standard time is then increased by the percentage applicable to the class of work in which the element falls. Personal allowances are the same for all classes of work. Peculiar conditions surrounding specific jobs sometimes demand special allowances.

Allowed Time.—The allowed time is the ultimate objective of an individual time study and should be a fair allowance for performing the job. It should represent the time which an operator of average skill would require when making an average effort under average working conditions and when experiencing the retarding effect of fatigue, unavoidable delays, and the like. Jobs requiring a set-up of machines or other equipment before production work can actually begin should be given an allowed time for the set-up and first piece and then an allowed time for each additional piece.

Checking.—Before the allowed time is placed on record, the time study should be thoroughly checked for accuracy in computations. The allowed time checked against the average overall time for each piece should disclose any very flagrant discrepancies, and will show whether the operator met the allowed time during the study, but this is not to be interpreted that allowed time must always exceed the average overall time. This comparison is only a general guide which should be used advisedly. The completeness of information should also be closely checked. Many studies are rendered valueless for future use merely because the job is not specifically identified and fully described.

Records and Filing.—All time studies and related data should be filed so that they are readily available for reference. Either the workman or the management is likely to wish to discuss a time value at any time, and the time-study man must have his data on hand so that he can answer all questions and justify any stand he may have taken.

The allowed-time values, as determined by time study, should be recorded and filed in a convenient manner for the use of time clerks or supervisors. A card index, filed according to numbers which identify the part, is generally found to be most satisfactory as a working file. A permanent official record should also be kept from which duplicate cards may be made out for the working file as the active ones become lost or soiled.

CHAPTER V

USE AND CONSTRUCTION OF PROCESS CHARTS

The first step in the study of any operation, after the desirability of making the study has been determined,[1] is to analyze all of the factors which surround the job. The purpose of doing this is to improve methods and conditions as much as possible before the actual timing of the operation is begun. Experience has shown that practically every industrial operation is capable of being improved if it is subjected to sufficiently detailed study by a qualified methods engineer, and if the repetitiveness of the job is sufficient, it is usually desirable to consider methods in some detail.

As a means of assisting in analyzing the factors surrounding an operation, process charts are invaluable. Process charts of themselves do not improve methods, but they permit the arrangement and presentation of a large amount of related data about a process in such form that they may readily be grasped by the analyst. Process charts help to present the nature of the problems which are involved in the improvement of any operation, and once the problems have been clearly stated, their solution is made easier.

Types of Process Charts.—The type of process chart that is used for studying any given process may be varied in accordance with the nature of the process and the objectives sought by the study. Any charted presentation of information connected with a manufacturing process may be considered to be a process chart. In fact, process charts need not be limited in their application to manufacturing processes, but are of equal value in connection with studies of office and clerical routine, sales problems, and other problems of business and industry.

From the broadness of this definition, it may be seen that it is possible to have a great variety of types of process charts and that the type which is used depends more or less upon the engineer

[1] H. B. Maynard and G. J. Stegemerten, "Operation Analysis," Chap. V, McGraw-Hill Book Company, Inc., New York, 1939.

who is constructing it. At the same time, there are six principal types which are commonly used for industrial analysis purposes. These types are as follows:

1. Operation process charts.
2. Flow process charts.
3. Man and machine process charts.
4. Operator process charts.
5. Progress process charts.
6. Miscellaneous types.

The first five types of charts are constructed in accordance with certain generally recognized principles. The sixth type is used to include all special and miscellaneous process charts that do not fall within the first five classifications.

The operation process chart is useful for showing in a related manner all of the operations performed in a given process. In effect, it gives a bird's-eye view of the process without including detail which might be confusing. Operation process charts are particularly useful for following processes where several parts have work done upon them before coming together to make a final assembly.

Flow process charts show the flow of material, forms, or operators through a given process. They present considerably more detail than the operation process chart and hence are more commonly useful for following single items. Both the operation process chart and the flow process chart usually show a number of steps in a process.

The man and machine type process chart narrows the field of analysis down to one or at most a few operations. The chart is used to show the relation between the part of the cycle which is under the control of the operator and the part which is under the control of the machine or process. This type of chart is useful for uncovering idle periods on the part of either the operator or the machine and for suggesting ways by which this idleness may be eliminated. It is also very useful in working out problems in connection with multiple machine operations or set-ups where one operator runs more than one machine.

Operator process charts give a still more detailed picture of a single operation. They show in detail exactly what the right and left hands of the operator are doing throughout the process and sometimes include the actions of other bodily parts.

Progress process charts are useful for studying the progress which has been made on any project. A common application is in connection with methods studies where they are used to show the accomplishments which have been made at any particular stage of the study.

Construction and Use of Operation Process Charts.—The information usually shown on the operation process chart consists of the following:

1. The operations.
2. The materials.
3. The time allowances.
4. The inspections.

As much additional information may be added to the chart as seems desirable. Such items as department, machine number,

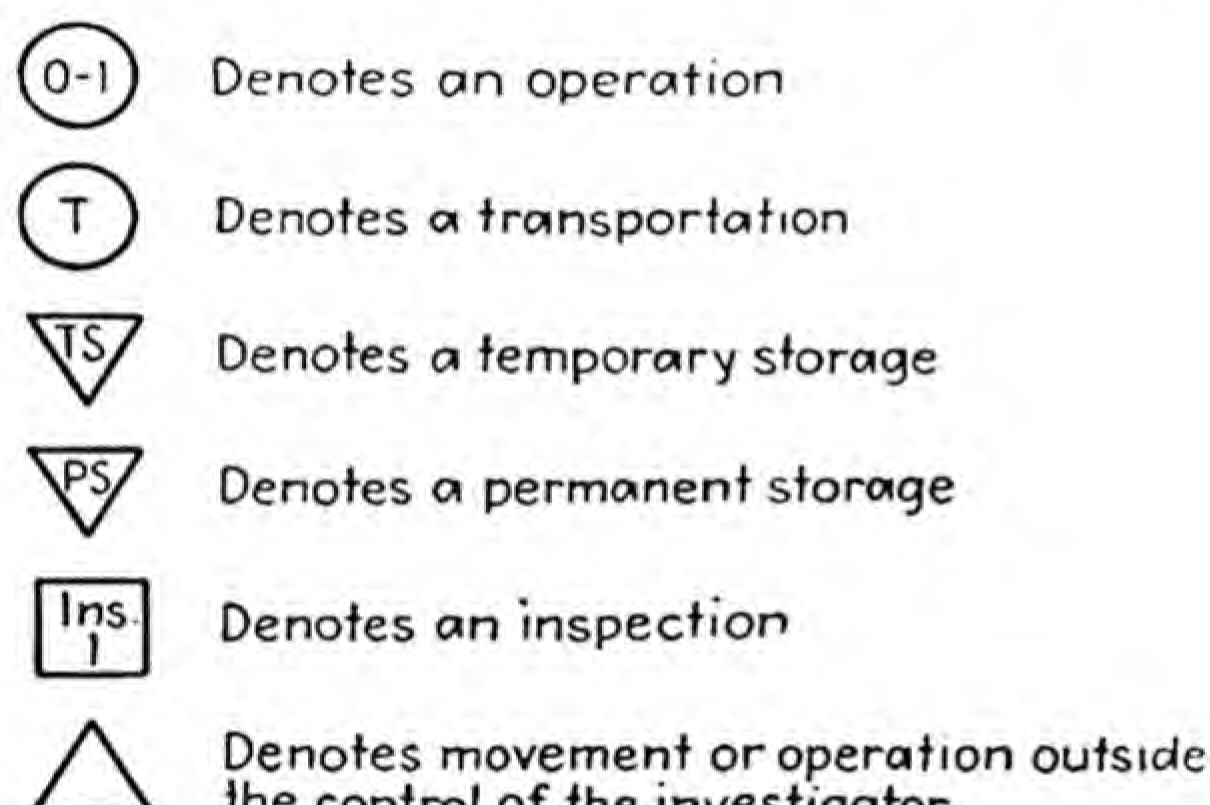


Fig. 2.—Standard symbols for operation and flow process charts.

male or female operator, and the like may be shown if desired, but care should be taken not to make the chart so complex that a grasp of the various operations in their relation to one another is obscured.

The symbols commonly used in constructing both operation and flow process charts are shown by Fig. 2. These symbols help to identify the type of information shown at each point by the process chart and enable those familiar with the symbols to size up a process quickly. Operation process charts are customarily drawn on plain paper of sufficient size to accommodate the information to be recorded. The flow of the process is represented by vertical lines on the chart and the flow of material into the process by horizontal lines. Figure 3 gives a graphical representation of the principles followed in constructing an operation process chart.

An indication of the way in which an operation process chart

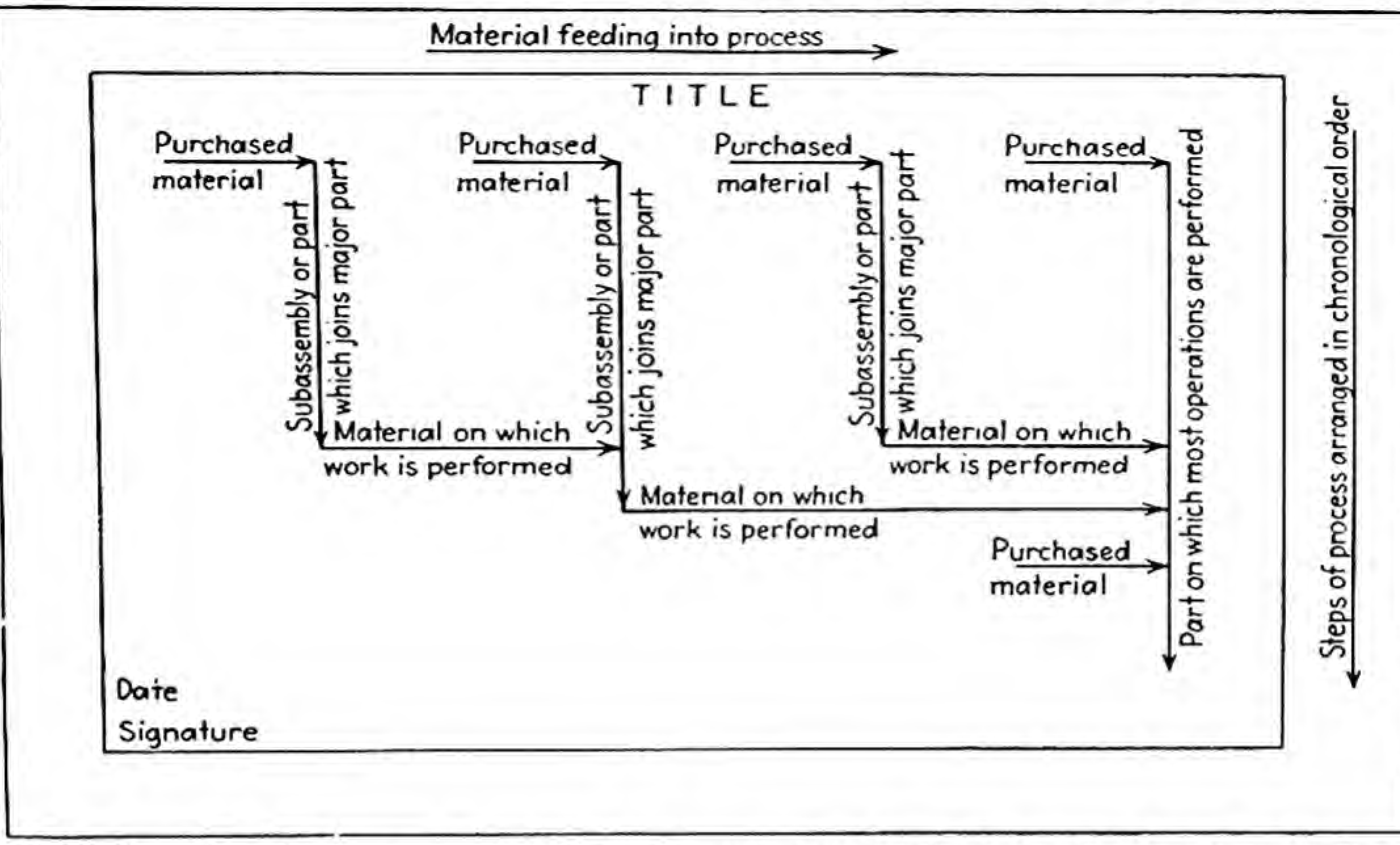


FIG. 3.—Graphic representation of principles of operation process chart construction.

permits one to obtain a quick, overall knowledge of a process and the manner in which the chart is constructed can be obtained by tracing through the steps of charting the operations performed during the manufacture and assembly of an electric connector used in an aircraft communication system. A photograph of the final assembly is shown by Fig. 4. The parts which go to make up the assembly are shown by the sketch, Fig. 5. *A* is the connector housing. *B* is an insulating washer which is pressed into the connector housing in the final assembly. *C* is a pin machined from brass rod. *D* is an insulating cylinder which goes over one end of the pin. *E* is an inner ferrule, which, when inserted in the connector cap *F*, is spun into the cup ferrule *G*.

FIG. 4.—Electric communication connector assembly.

To make the operation process chart, the first step is to select the item of the assembly which has the greatest number of operations performed upon it. This is usually the largest part of the assembly, although not necessarily so. Any other part could be chosen as a starting point, but the chart will present the most pleasing appearance if the part with the most operations is charted first. Beginning at the upper right-hand corner of the

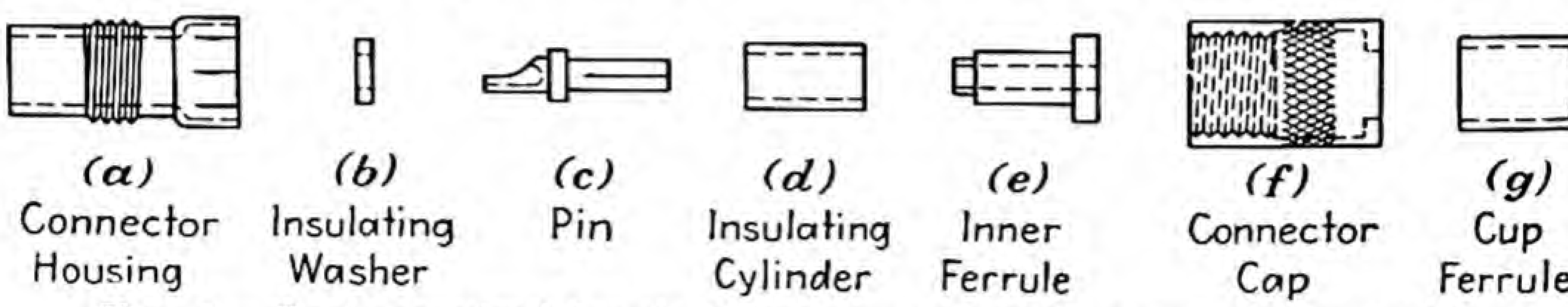


FIG. 5.—Parts required for electric communication connector assembly.

chart, the material of which the part is made is recorded. In this case, it is bronze rod. A horizontal line drawn under the words "bronze rod" indicates that this material feeds into the vertical flow line of the process. The first operation performed on the connector housing is "turn, drill, ream, thread, and cut off." The time required to perform this operation is 0.0165 hour. On the vertical flow line about $\frac{3}{16}$ inch from the horizontal material line, an operation symbol is drawn. The identification, *O*-1, is placed in the center of the symbol, since it represents the first operation to be charted. To the right, a description of the

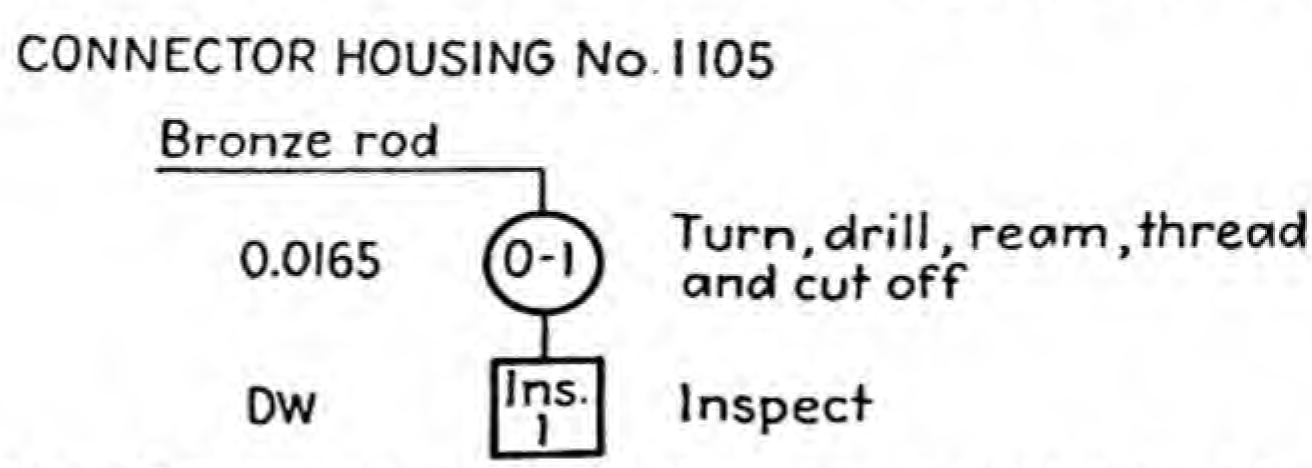


FIG. 6.—First step of operation process chart construction for electric connector.

operation is given, namely, "turn, drill, ream, thread, and cut off." To the left, the allowed time is shown. This is illustrated by Fig. 6.

The next thing which happens is an inspection. Therefore, the inspection symbol, a square, is drawn in the vertical flow line of the process. Inside the square is written, "Ins-1." To the right of the square, the word, "Inspect," is written, and since this is a day work job, the abbreviation, "DW," is recorded to the left.

In a similar manner, the other operations and inspections are shown until another part of the assembly joins the connector housing. Immediately after *O*-5, the pin *C* joins the process. It is shown feeding in on a horizontal material line, but since work has been done on the pin to get it in its finished form, this must also be charted. The procedure followed in the case of the connector housing is repeated for the pin. Brass rod is shown flowing into a vertical process flow line. The operations and inspections are charted as before. The first operation performed on the pin is "turn small *OD* and cut off." This would be *O*-1 for the pin, but since the symbol *O*-1 has already been used for the connector housing, the convention is to use the next available operation number in order to avoid duplication of numbers on the chart. The numbers are used for reference purposes and therefore should not be repeated.

All other parts are added to the chart in the same manner. If work has been done upon them, the operations and inspections are charted. If the material is a purchased item, it is merely shown feeding into the process on a horizontal material line. The final chart, covering the entire process of the manufacturing and assembly of the electric connector, is shown by Fig. 7. From this chart, a clear idea can be obtained of the process as a whole. The relation of the various operations to one another is clearly apparent, and the relative time required by each operation is seen at a glance.

Construction and Use of Flow Process Charts.—The flow process chart is used to follow men, material, forms, or the like through a complete process. In addition to showing the operations and inspections, the flow chart also shows the transportations, with the distance involved, and the storages, both permanent and temporary. Material is considered to be in temporary storage when it will be moved on through the process in a reasonable length of time without special action on the part of any individual other than those who would normally require the material to do their routine task. Material is said to be in permanent storage when definite action on the part of some responsible individual is necessary to start it in motion. Material in a storeroom where a material requisition is needed to place it in motion is said to be in permanent storage. Material on the floor beside a machine awaiting its turn on the machine is considered to be in temporary storage.

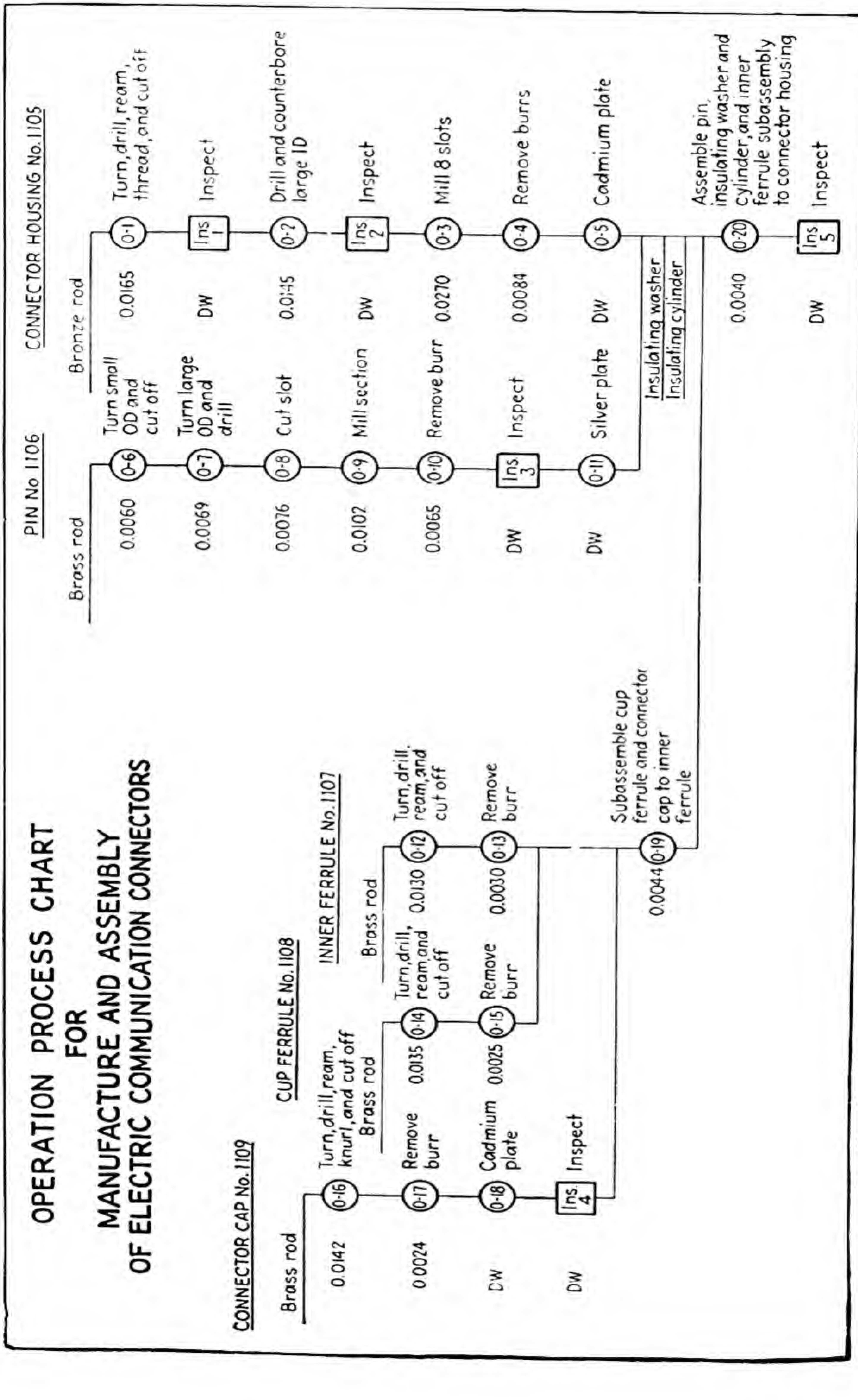


Fig. 7.—Operation process chart for manufacture and assembly for electric communication connectors.

FLOW CHART

PROTECTIVE CAP No. 139204

DISTANCE	TIME DEC HRS.		
		△	Steel placed on loading platform by supplier
	0.0500	O-1	Load on skid
150'	0.0347	T-1	Deliver to steel storage
	0.0438	O-2	Unload
	48.0000	TS	Await steel requisition
	0.0500	O-3	Load skid
75'	0.0267	T-2	Deliver to blanking press #408
	0.0438	O-4	Unload beside #408
	0.0321	O-5	Open bundle
	0.0467	O-6	Load operator's table
	0.5000	TS	Await machine setup
	0.0004	O-7	Blank (4 at a time)
	0.0001	O-8	Stack on floor behind machine
	6.0000	TS	Wait for stockman
	0.0200	O-9	Load hand truck
100'	0.0300	T-3	Deliver to draw press #818
	0.0300	O-10	Unload beside #818
	5.2500	TS	Wait for machine setup
	0.0015	O-11	Draw
	0.0001	O-12	Stack on skid beside machine
	0.7500	TS	Wait for electric truck
50'	0.0143	T-4	Deliver to piercing machine #851
	2.3600	TS	Wait for machine setup
	0.0010	O-13	Pierce
	0.0001	O-14	Stack on skid beside machine
	0.7500	TS	Wait for electric truck
500'	0.1600	T-5	Deliver to storage
	0.0200	O-15	Unload into bin
		PS	Await shipping instructions

FIG. 8.—Flow process chart of protective cap.

A typical flow chart for a part drawn from sheet steel is shown by Fig. 8. The flow chart covers the movement of the material from the time the material enters the plant until the finished item is placed in finished stock ready for assembly. Only three operations of the type which would be shown on the operation process chart appear in the process. However, a great many other things happen to the material besides these three operations, and they are all shown on the flow chart. In this way, a quick understanding is obtained of the indirect operations which are performed as supplementary to the direct operations. As seen by the chart, they are more numerous and require more time than the direct operations. This is often the case, and a flow chart study serves to bring out this fact clearly.

Two of the most important items of the information obtained from the flow chart are the distance the material travels and the amount of time it spends in temporary storage. The distance traveled is important because material handling is involved. Material handling adds to the cost of the part without adding to its value and, therefore, should be reduced to a minimum. Time spent in temporary storage is probably even more important, for it represents several inefficiencies if it is unduly long. In plants which are not set up for continuous production, time spent in temporary storage is often more than the time spent in work. Time spent in temporary storage lengthens delivery schedules; hence, it is important when quick delivery is required. In addition, large amounts of time spent in temporary storage represent large amounts of material in process and indicate an unduly high work-in-process inventory. Furthermore, material in temporary storage occupies floor space, and hence excessive temporary storage usually is found to accompany plant congestion.

In constructing a flow process chart, the chart is started at the upper left-hand corner of the sheet. Most flow charts of single parts are long and narrow, and hence, it is customary to include two columns of the chart on standard $8\frac{1}{2}$- by 11-inch paper. As the chart is developed, it is advisable to go into the plant and follow each step of the process personally rather than to attempt to do the work at the desk. When this is done, the possibility that steps of the process will be overlooked is reduced, and the resulting analysis will be more thorough. Each operation, inspection, transportation, and storage from the time

material enters the plant until the process is completed is charted in its proper turn. Information concerning the nature of the operation, the time involved, the distance traveled, and similar information is shown on the chart. Since the chart itself is of necessity rather detailed, it is again desirable to avoid including any unessential information which might confuse rather than clarify the interpretation of the chart. The chart itself may be drawn freehand and later copied neatly, or an attempt may be made to draw a neat chart from the start. In any case, neatness is desirable, for it makes the chart easier to read and interpret. In order to facilitate the drawing of the symbols, small celluloid templates may be used containing a circle, square, and triangle.

Process Charts and Plant Layouts.—Before a plant layout study can be begun, it is necessary to have detailed information concerning the processes which are to be performed. Operation and flow process charts can be a valuable aid in this connection. The operation process chart is particularly valuable where a layout is being made for progressive operation. Because of the way in which it is drawn, the chart of itself almost suggests the layout. The vertical flow lines indicate the order in which the machines should be arranged, and the horizontal material lines indicate the points at which material should feed into the process. Since the major part is usually charted to the right of the form, this can be considered to represent the main assembly line. The minor parts then appear as feeding in on sub-assembly lines at the desired points.

Where work is done progressively, it is highly important that all operations balance with respect to time. Since the operation process chart shows the time required for each operation, the extent of balance or unbalance can be ascertained from the chart. Usually, the production required per day is first determined from sales and production schedules. From this, the number of each kind of machine necessary to get out the desired production can be computed. It is seldom that a process will balance exactly at the outset, but when the points of unbalance are known, it is usually possible to shift operations or parts of operations about until approximate balance is obtained. Assume, for example, that a production of 950 electric connectors of the type covered by the operation process chart, Fig. 7, are required per 8-hour day. To obtain this production, one connector must be finished every $8 \div 950 = 0.0084$ hour.

Looking over the operation process chart, it is found that the time for the first operation on the connector housing is 0.0165 hour. Therefore, two machines will have to be provided for this operation in order to turn out one housing every 0.0084 hour. On the second operation, the time is 0.0145 hour. Here only about 1.7 machines would be needed. It is, of course, impossible to supply a fractional machine, and therefore two must be provided. Some arrangement must then be made to utilize the time of the operators over and above that required to turn out the daily production requirements. For example, a set-up might be made whereby the operators work only 7 hours a day on operation 2, after which they perform some other operation. The third operation requires 0.0270 hour. Three machines will be required for this operation, although theoretically they will not be busy quite all day. The fourth operation requires exactly the theoretical amount of time to perform, and therefore one operator will be used for this operation.

When the final assembly operation is considered, it is found that the time required is only 0.0040 hour per piece. Thus, on this operation, one operator would be able to produce more than twice the production requirements. Therefore, it will be necessary to find something else for him to do. Looking over the chart, it will be seen that a similar operation, *O*-19, requires 0.0044 hour. If the operator is given both assembly operations to do, the total time per piece will be 0.0084 hour which will yield exactly the required production. Similarly, all other operations may be balanced.

Where work is not of a progressive nature, operation process charts are useful for determining the general locations of machines and equipment, but in addition, flow charts should be used in connection with the layout study. The flow chart shows distances moved and time spent in temporary storage. If the distances moved are excessive, they can perhaps be reduced when the new layout is being made. Temporary storage is important in that it represents floor space occupied by material. Hence, this information is essential to the layout engineer if he is to provide sufficient space for material.

Construction and Use of Man and Machine Process Charts.—In some kinds of work, there are times during the operating cycle when the operator has nothing to do. The operation is outside of his control, as for example when a machine is making a cut

under power feed, and the operator has nothing to do other than to wait until the cut is completed. This time should be regarded as idle time and an attempt made to find something for the operator to do. He may utilize the idle time, for example, to file burrs from the part which has just been completed, or he may be given additional machines to operate. In any case, a study should be made to make sure that the operator has the time to perform the additional work and that it will not increase his fatigue to any undue extent.

In making a study of this kind, the man and machine chart can be a valuable aid. The man and machine chart shows the relation between man time, where the operation is under the control of a man, and machine or process time, where the man has no work to perform.

For example, assume that a time study taken on milling the end of a certain contact support, Dwg. 763103 on a No. 2 Cincinnati milling machine, gives the following data:

Pick up part and tighten vise	.0018
Start machine	.0004
Advance table 2 inches and engage feed	.0010
Mill end	.0040
Stop machine	.0004
Return table 5 inches	.0010
Loosen vise and lay part aside	.0010

This information placed in a man and machine chart form is shown by Fig. 9. Man time and machine time are shown separately, and it is seen that when the man is working the machine is idle, and vice versa. The desirable condition is to have both man and machine fully occupied during the operation cycle. One way of approaching this is to give the operator additional machines to run. If, for example, the operator above were given a second milling machine to run, the operation cycle would appear as shown by the man and machine chart, Fig. 10. When running one machine, the man is idle 0.0040 hour, and the each-piece time is 0.0096 hour. If an additional machine is provided, the operator is able to work steadily and the each-piece time is reduced to 0.0067 hour.

The Operator Process Chart.—The operator process chart is a tool of motion study rather than of primary operation analysis. It may be used to study the motions performed by the various bodily parts of the operator during an operation, although it

MAN AND MACHINE CHART
MILL END OF CONTACT SUPPORT-DRAWING 763103
No. 2 CINCINNATI MILLING MACHINE

	MAN	MACHINE
Pick up part and tighten vise	0.0018	
Start machine	0.0004	
Advance table 2" and engage feed	0.0010	
Mill end		0.0040
Stop machine	0.0004	
Return table 5"	0.0010	
Loosen vise and lay part aside	0.0010	
Total each piece time	0.0096	

FIG. 9.—Man and machine process chart of milling machine operation; operator runs one machine.

MAN AND MACHINE CHART
MILL END OF CONTACT SUPPORT-DRAWING 763103
No. 2 CINCINNATI MILLING MACHINE

	MAN		MACHINE 1	MACHINE 2
Pick up part and tighten vise	0.0018			
Start machine	0.0004			
Advance table 2" and engage feed	0.0010			
Walk to machine #2	0.0011			
Stop machine	0.0004			
Return table 5"	0.0010	Mill end	0.0040	
Loosen vise and lay part aside	0.0010			
Pick up part and tighten vise	0.0018			
Start machine	0.0004			
Advance table 2" and engage feed	0.0010			
Walk to machine #1	0.0011			
Stop machine	0.0004			
Return table 5"	0.0010	Mill end		0.0040
Loosen vise and lay part aside	0.0010			
Total cycle time	0.0134			
Each piece time	0.0067			

FIG. 10.—Man and machine process chart of milling machine operation; operator runs two machines.

more commonly charts the movements of the two arms only. The chart may show as much or as little information as is considered desirable, but here again it is found that the simpler charts are more readily understood.

Figure 13 shows a simple operator process chart which was drawn up to aid in visualizing completely each detailed step in the operation of assembling the arc shield pictured in Figs. 11 and 12, in accordance with the methods then in use, and to assist in the determination of a better method. The activity of these arc shields was originally quite small, and it was not considered worth while to devote much time to the study of the operation.

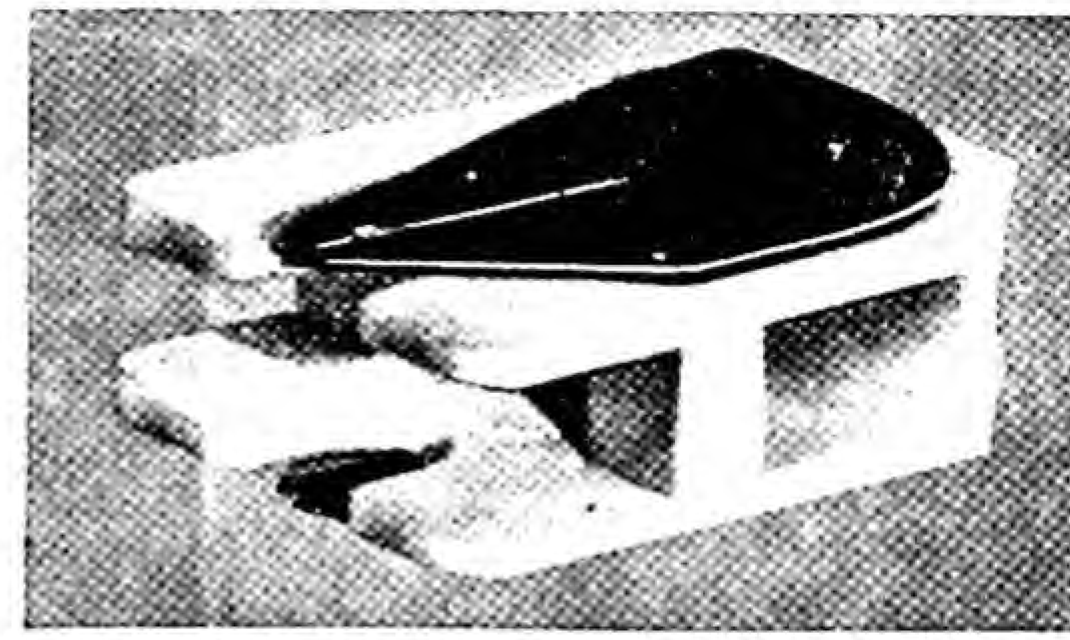


FIG. 11.—Complete arc-shield assembly.

Subsequently, they were ordered in increasingly greater quantities, until the time-study department decided to analyze the operation thoroughly to determine the best method of doing the work. The method followed at the time the study was begun was one which had been devised without instruction by the operator who worked on the job when it first came through

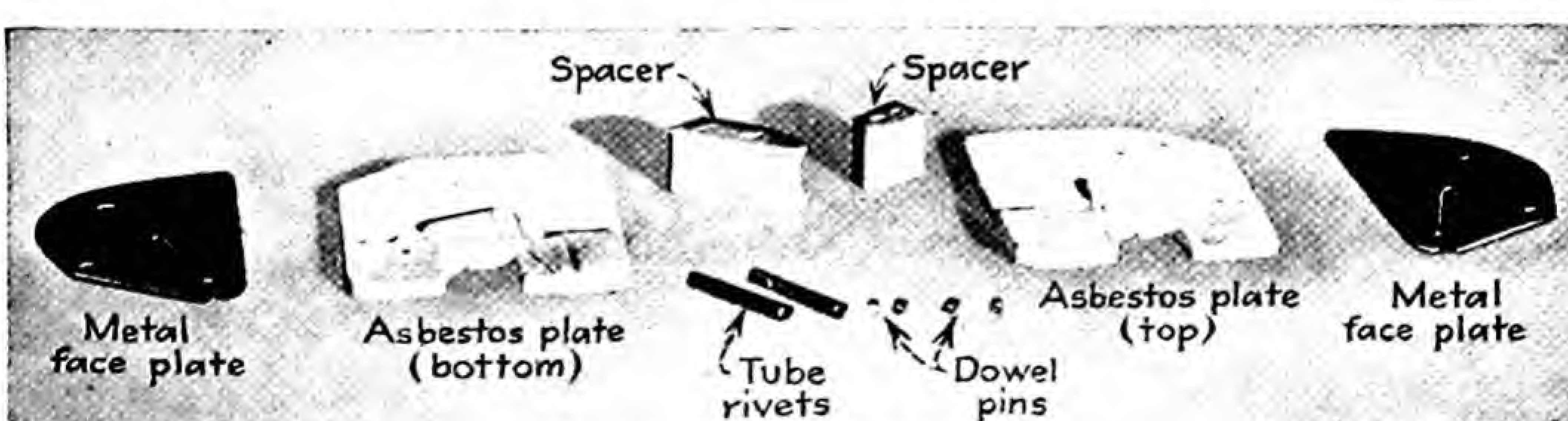
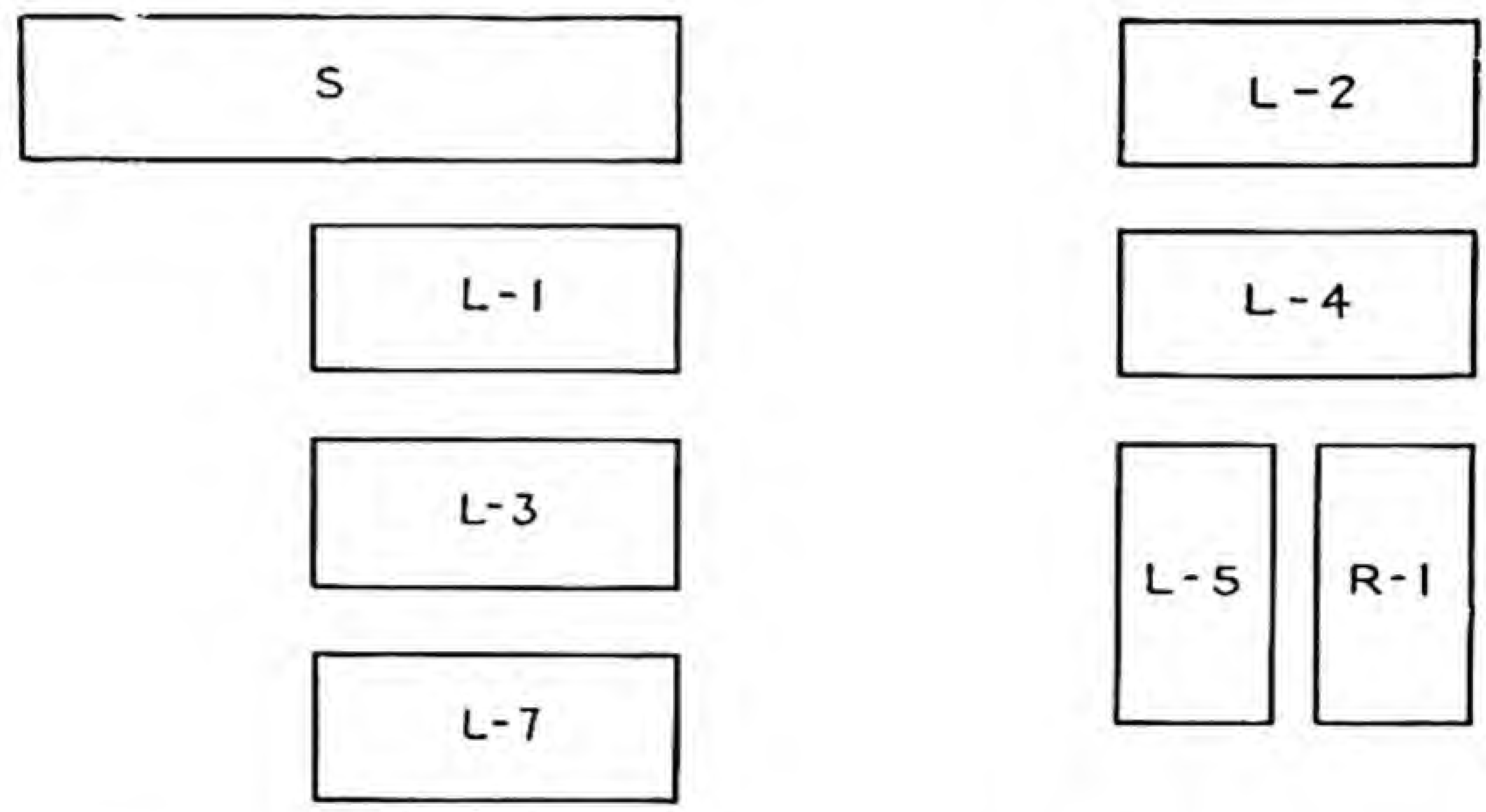


FIG. 12.—Arc-shield details.

the shop. Little or no thought had been given to the location of the materials on the bench, the use of fixtures, or the like. The present operators were skilled in following the existing method, and no fault could be found with the effort which they exerted, but it was evident from observation that the method could be greatly improved.

A careful study was first made of the existing method, the right and the left hands of the operators being studied separately



LEFT HAND	RIGHT HAND
Move to bottom asbestos plate at L-1	Move to dowel pins at R-1
Grasp asbestos plate	Grasp two dowel pins
Move to surface plate	Move to asbestos plate
Hold	Insert two dowel pins in plate
Move to spacer at L-2	Move to hammer
Grasp one spacer	Grasp hammer
Move to asbestos plate	Move to asbestos plate
Position spacer over one dowel pin	Idle
Hold	Tap spacer with hammer
Move to spacer at L-4	
Grasp spacer	
Move spacer to asbestos plate	
Position spacer over dowel pin	Idle
Hold	Tap spacer with hammer
Move to rivets at L-5	Move hammer aside
Grasp two rivets	Release hammer
Move to spacer	Move to dowel pins at R-1
	Grasp two dowel pins
Idle	Move to spacer
Insert one rivet through spacer	Insert one dowel pin in spacer
Move to spacer	Move to spacer
Insert other rivet through spacer	Insert other dowel pin through spacer
Move to top asbestos plate at L-3	
Grasp asbestos plate	

(continued on next page)

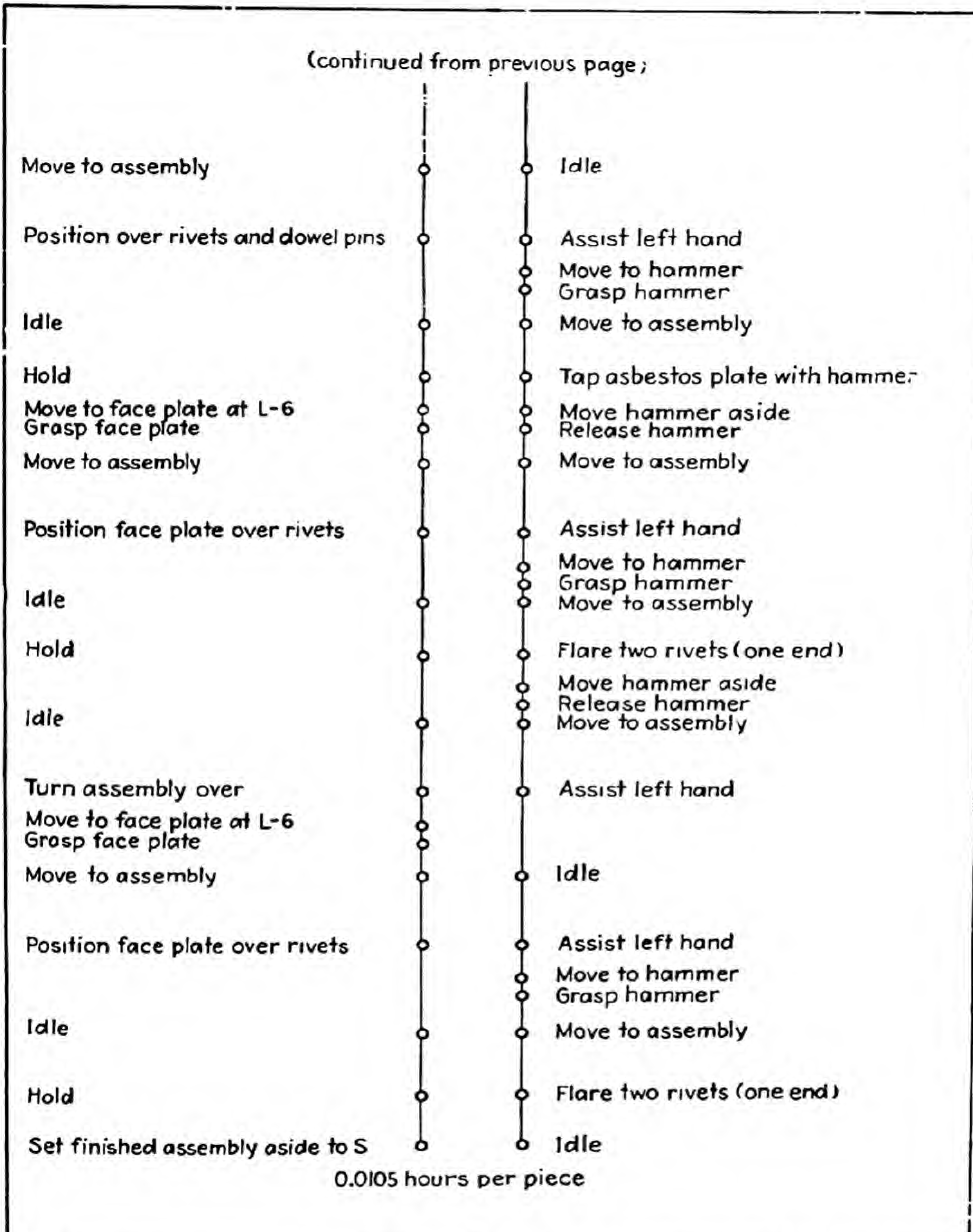
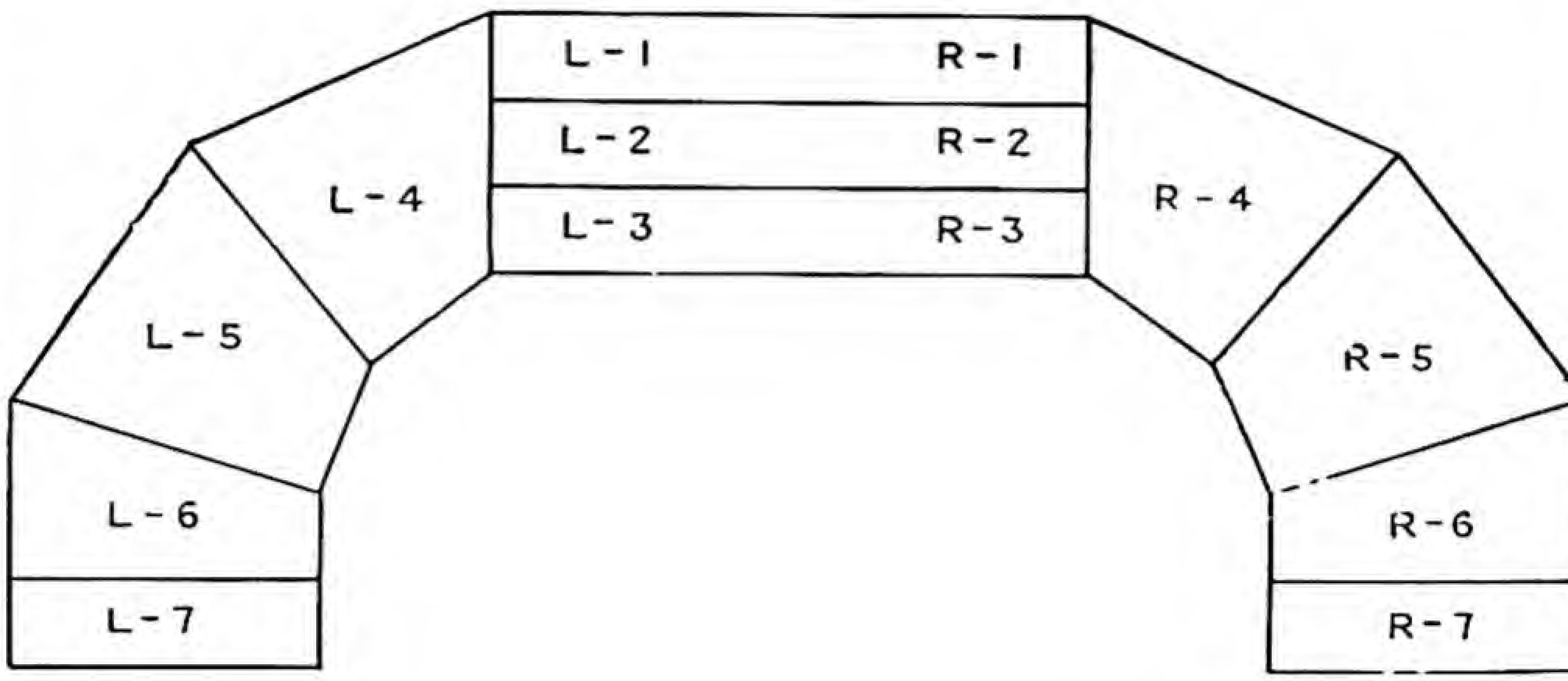


Fig. 13.—Operator process chart of old method of arc-shield assembly.



LEFT HAND	RIGHT HAND
Move to rivets at L-7	Move to rivets at R-7
Grasp two rivets	Grasp two rivets
Move to fixture	Move to fixture
Insert rivets in fixture	Insert rivets in fixture
Move to face plate at L-1	Move to face plate at R-1
Grasp face plate	Grasp face plate
Move to fixture	Move to fixture
Position over rivets	Position over rivets
Move to bottom asbestos plate at L-2	Move to bottom asbestos plate at R-2
Grasp asbestos plate	Grasp asbestos plate
Move to fixture	Move to fixture
Position over rivets	Position over rivets
Move to dowel pins at L-6	Move to dowel pins at R-6
Grasp two pins	Grasp two pins
Move to assembly	Move to assembly
Insert pins in asbestos plate	Insert pins in asbestos plate
Move to spacer at L-5	Move to spacer at R-5
Grasp spacer	Grasp spacer
Move to assembly	Move to assembly

(continued on next page)

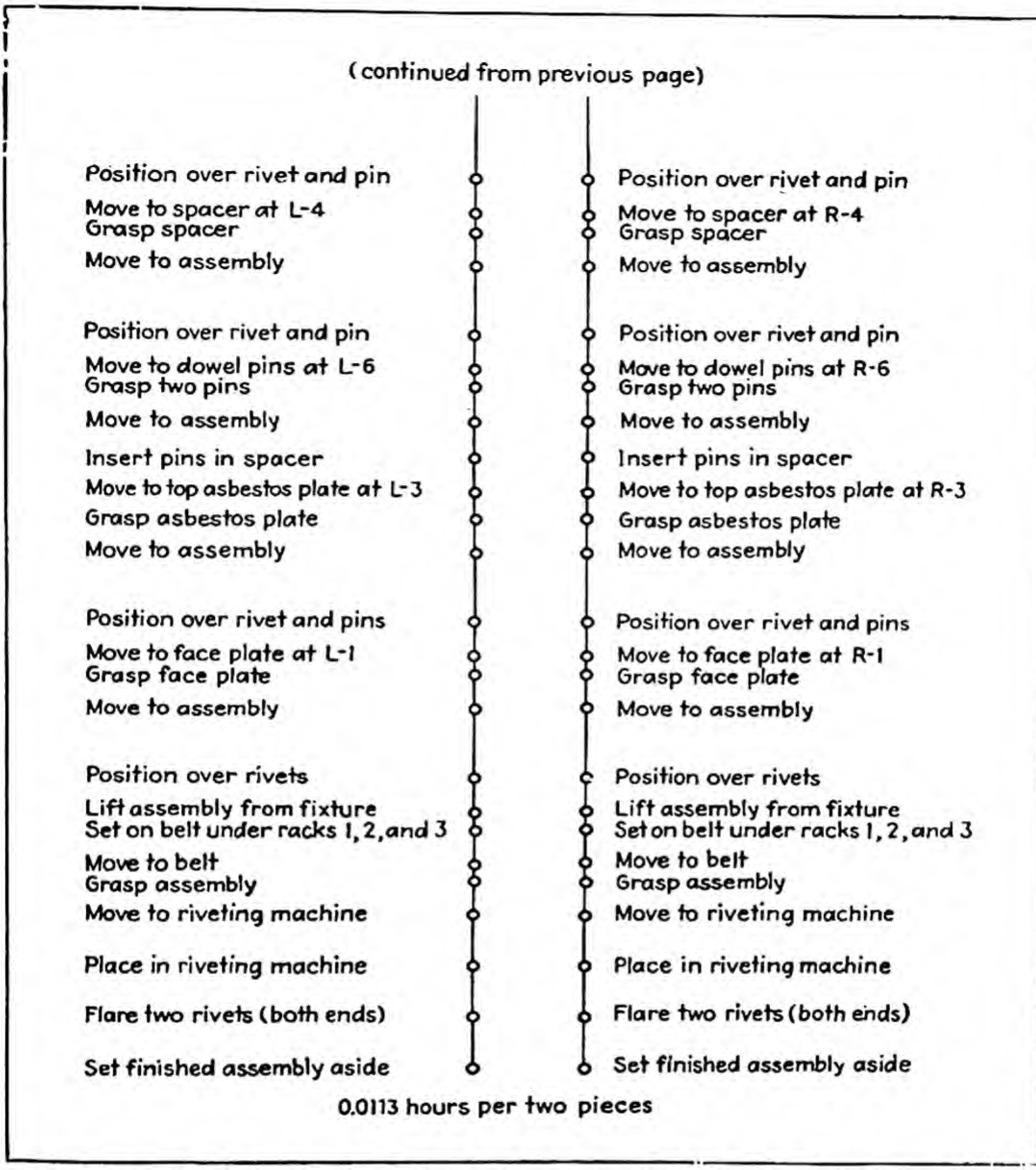


FIG. 14.—Operator process chart of new method of arc-shield assembly.

and together, and the results were charted on the operator process chart, Fig. 13. The sequence of the operations was briefly as follows: Pick up bottom asbestos plate, Fig. 12, and place on surface plate; insert two dowel pins in bottom asbestos plate; pick up first spacer and locate over one dowel pin, aligning approximately with rivet holes; pick up second spacer and locate over other dowel pin; pick up two tubular rivets and insert these through the spacers and the bottom asbestos plate; insert two dowel pins in spacers; pick up and place top asbestos plate over rivets and locate on dowel pins; pick up face plate and place over rivets; flare rivets with peening hammer; turn assembly over; pick up and place other face plate over rivets; and flare other end of rivets.

A study of this procedure and of the operator process chart shows that a number of the principles of correct working practices were being violated. The faults were studied and corrected one by one, until finally the method shown by the operator process chart, Fig. 14, was devised. A double holding fixture was provided; the tubular rivets were flared on one end at the time of cutting to length; and at length the new method was taught to the operators. The sequence followed by each hand was: Pick up two rivets and locate in fixture; pick up face plate and locate over rivets; pick up two dowel pins and place; pick up second spacer and place over rivet and pin; pick up two dowel pins and insert one in each spacer; pick up top asbestos plate and place over rivets and pins; pick up face plate and place over rivets; set assembly aside; pick up assembly; flare two rivets on riveting machine; and set finished assembly aside.

As the result of this study and the changes made, instead of completing one assembly in 0.0105 hour, the operators were able to complete two assemblies in 0.0113 hour, or in 0.00565 hour per assembly, a saving of 46.2 per cent.

The old and new procedures are described in this example both in words and by the operator process charts. A comparison of the two descriptions will show that it is easier to understand the operation from a study of the operator process chart than from the written description alone. The clarity provided by operator process charts alone makes their preparation worth while in many cases.

An additional example of a more comprehensive form of operator process chart is shown by Fig. 80, Chap. XI.

The Progress Process Chart.—As the result of detailed analysis, a number of suggestions for improvement are likely to be uncovered in connection with the operation or process being studied. Suggestions for improvement are much easier to make than to put into effect; hence, realization usually follows after the suggestion by a considerable period. If the study is at all

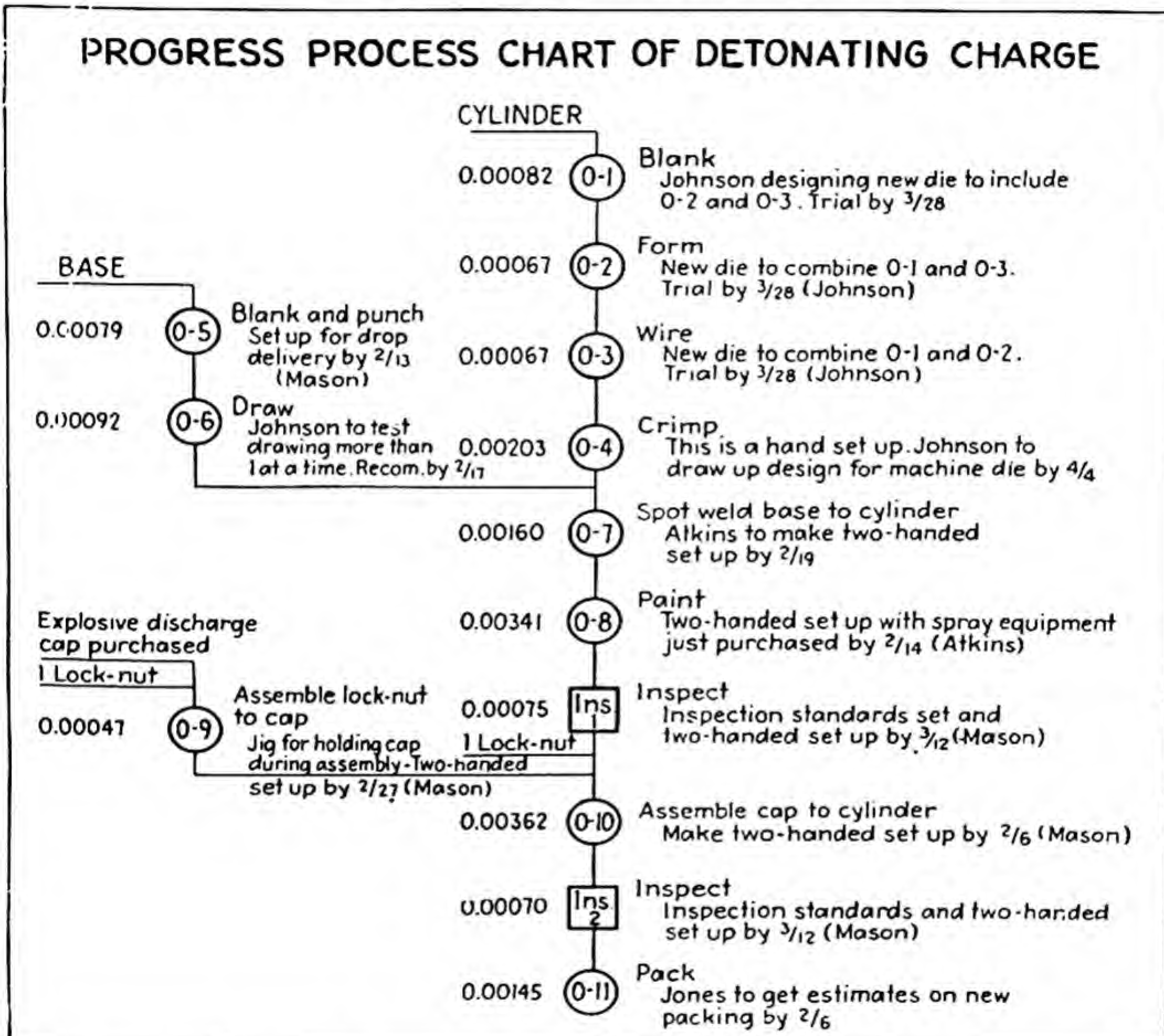


FIG. 15.—Progress process chart.

extensive, there will soon be a number of suggestions in various degrees of completion, and quite often the status of the study becomes confused. When this is the case, it is advisable to make a progress process chart in order that a fresh starting point for future action may be determined. The progress process chart follows the operation process chart in form and shows the exact status of every operation undergoing study. Figure 15 is an example of this type of process chart.

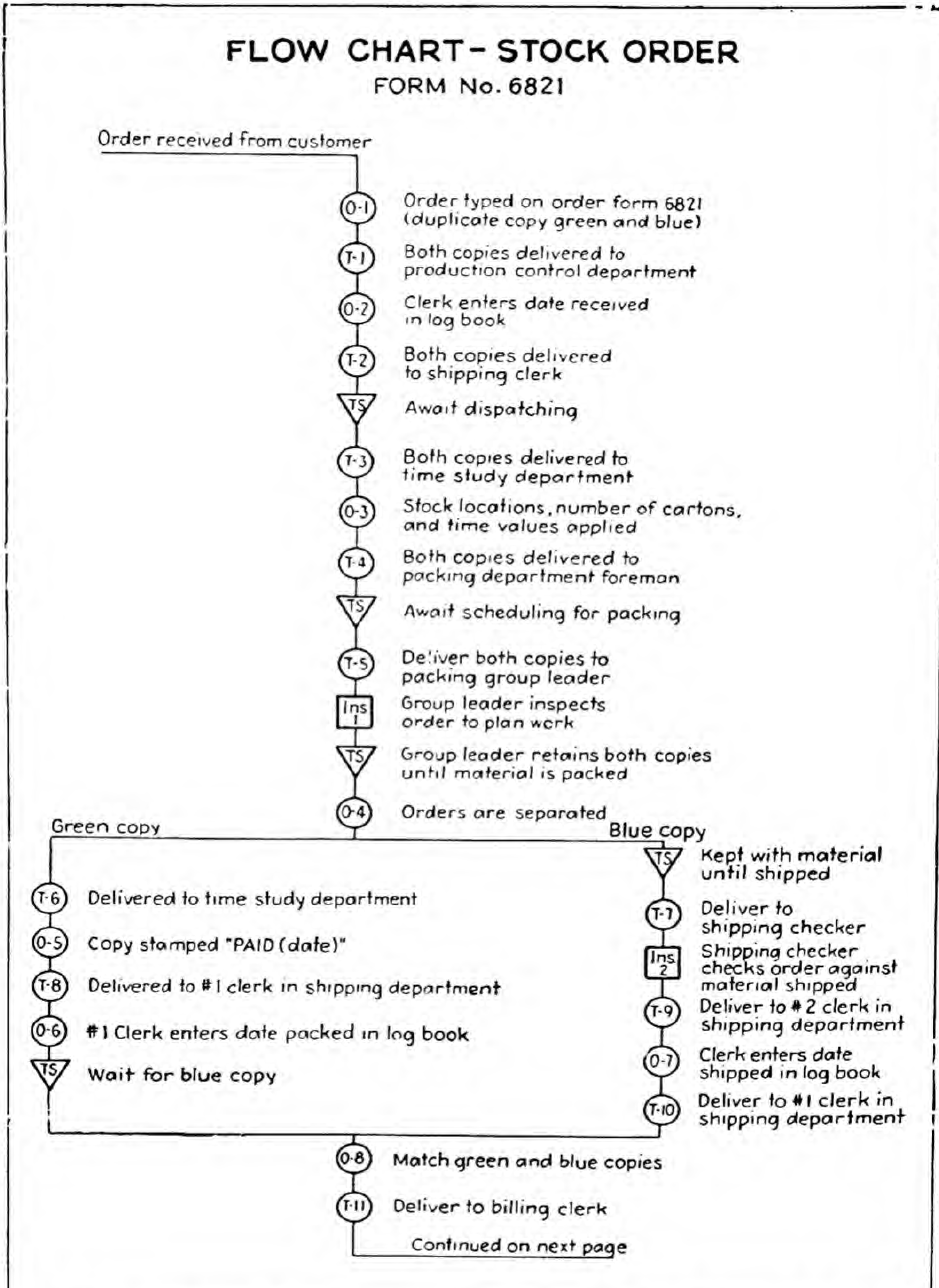


FIG. 16.—Modified operation process chart for clerical routine analysis.

Process Charts for the Study of Office or Clerical Routine.—Office or clerical procedures are often difficult to visualize clearly as a whole, and for this reason process charts can be of value in an analysis of this type of work. Either the operation process chart or the flow process chart may be used, depending upon the amount of detail it is desired to show. In the study of an office procedure, the object customarily followed is the form or forms used. Figure 16 shows a modified operation process chart which includes temporary storage and transportation information for an order procedure from the time the order is typed until the material is shipped and the forms are returned to the accounting department for pricing and invoicing.

CHAPTER VI

OPERATION ANALYSIS

A general understanding of the nature of a given problem is obtained from a first overall analysis made with the aid of operation and flow process charts. Often, this general analysis uncovers major inefficiencies which may be eliminated at once. At length, however, no further improvements are suggested by overall analysis, and it becomes necessary to go into more detail if additional accomplishments are to be made. At this point, therefore, each operation is considered in detail, and the procedure known as operation analysis is applied.

Operation analysis is the procedure employed to study all major factors which affect a given operation. The study is made by approaching the job with an open mind and asking either of oneself or of others questions which are likely to lead to methods improving ideas. If done systematically, so that the possibility of overlooking factors which should be considered is minimized, worth-while improvements are almost certain to result.

Mental and Written Analysis.—Every operation should be analyzed at least briefly before being timed. The time-study man should make operation analysis a definite part of his procedure and should apply it as the first step of every study. The amount of time which may be profitably devoted to operation analysis depends upon the repetitiveness of the work, the expected life of the job, and the proportion of the operation cycle which involves human labor. In other words, if a large amount of labor is involved per year and if the job may be expected to last a long time, it will pay to devote more time to the study of the job than if low activity, short life, and low labor content reduce the possible total savings.[1]

Mental analysis is better than no analysis at all and should be applied at least briefly to any job that is considered worth study-

[1] H. B. Maynard and G. J. Stegemerten, "Operation Analysis," Chap. V. McGraw-Hill Book Company Inc., New York, 1939.

ing. Written analysis requires more time to make but, since it is more thorough and usually accomplishes greater results, it should be used wherever its use can be economically justified.

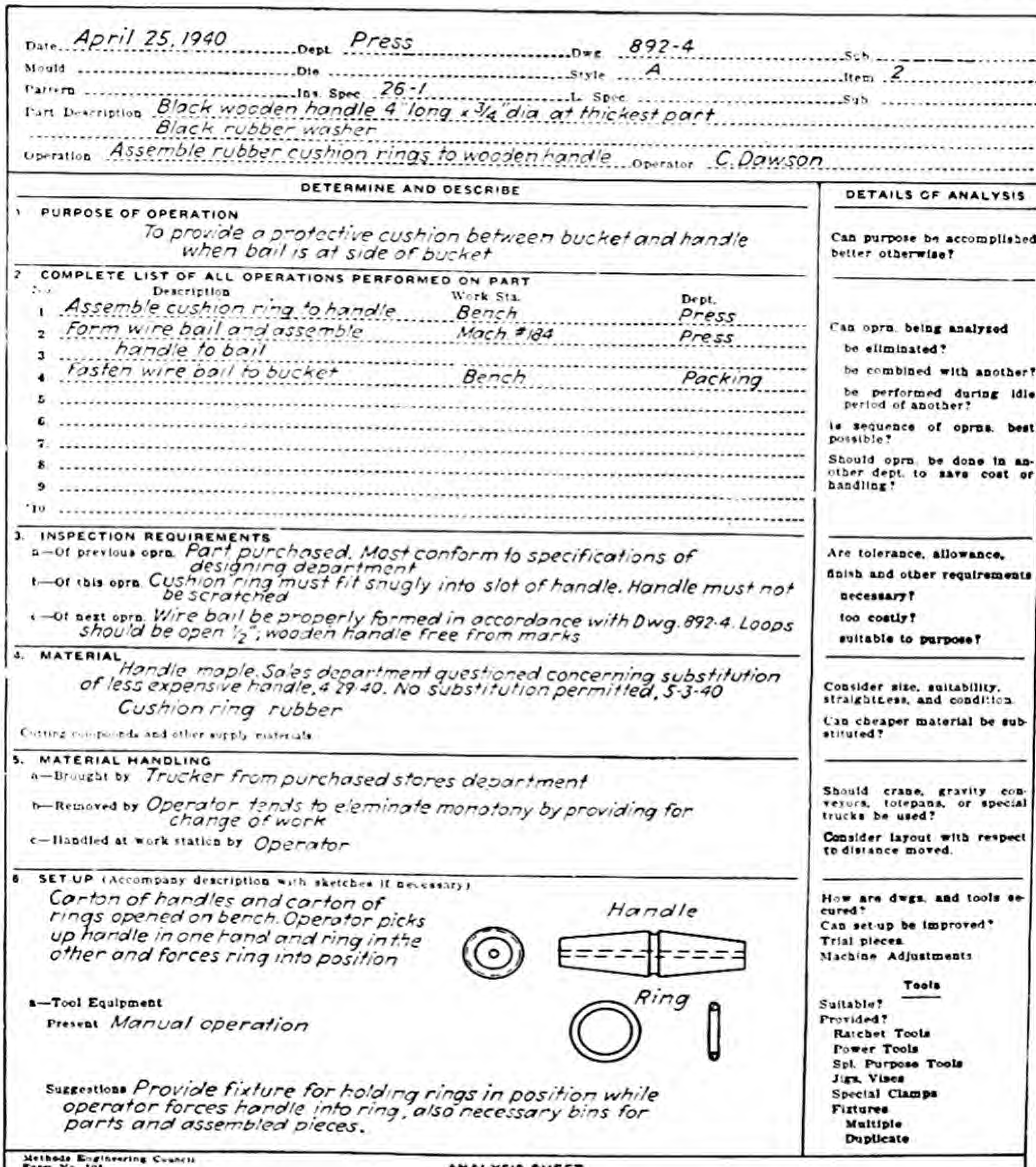
The Analysis Sheet.—It is important to begin the analysis at the proper point and to follow systematically with a consideration of each factor that may offer possibilities for cost reduction. The nine major points of operation analysis are as follows:

1. Purpose of operation.
2. Complete survey of all operations performed on part.
3. Inspection requirements.
4. Material.
5. Material handling.
6. Set-up and tool equipment.
7. Common possibilities for job improvement.
8. Working conditions.
9. Method.

In order to insure that operation analyses are made systematically and that no possibility for improvement is overlooked, a form known as the "analysis sheet" may be used. This form, filled in for the analysis of the operation of assembling rubber cushion ring to wooden handle, is shown by Figs. 17 and 18. Wherever the savings possibilities justify it, the form should be used and filled in completely. In this way, not only will a thorough job of analysis be made, but also a record of the analysis will be produced. If the operation is not of sufficient importance to justify a written analysis, the steps outlined by the analysis sheet should be followed during the course of the mental analysis.

Purpose of Operation.—Before one can successfully pass judgment or determine the best and most efficient way to perform a given operation on a part, he must know why the operation is being done and the function which the part will fulfill in the ultimate use and application of the finished product. It would be entirely unnecessary to put a high-grade finish on something that will eventually be hidden away in an automobile or some other piece of apparatus as long as this finish is not necessary to efficient and lasting performance. A plasterer does not attempt to distribute the rough plaster on the walls of a house as evenly or as smoothly as he does the finish plaster. A painter does not take the time or the care in painting preliminary coats that he does in painting the finish coat and the trimmings. In a home, an ordinary floor made to be covered with a rug does not call

for the same workmanship as does the hardwood floor of a ballroom. Electric controllers used on elevators in large department stores and hotels usually have an ornamental design and finish; on the other hand, those used in steel mills and similar places


Date April 25, 1940 Dept. Press Dwg. 892-4 Sch.
Mould Die Style A Item 2
Pattern Ins. Spec. 26-1 L. Spec. Sub.
Part Description Black wooden handle 4" long × 3/4" dia. at thickest part
Black rubber washer
Operation Assemble rubber cushion rings to wooden handle Operator C. Dawson

DETERMINE AND DESCRIBE

1. PURPOSE OF OPERATION
To provide a protective cushion between bucket and handle when bail is at side of bucket

2. COMPLETE LIST OF ALL OPERATIONS PERFORMED ON PART

No.	Description	Work Sta.	Dept.
1	Assemble cushion ring to handle	Bench	Press
2	Form wire bail and assemble	Mach. #184	Press
3	handle to bail		
4	Fasten wire bail to bucket	Bench	Packing
5			
6			
7			
8			
9			
10			

3. INSPECTION REQUIREMENTS
a—Of previous opra. Part purchased. Most conform to specifications of designing department
b—Of this opra. Cushion ring must fit snugly into slot of handle. Handle must not be scratched
c—Of next opra. Wire bail be properly formed in accordance with Dwg. 892-4. Loops should be open 1/2"; wooden handle free from marks

4. MATERIAL
Handle maple. Sales department questioned concerning substitution of less expensive handle, 4-29-40. No substitution permitted, 5-3-40
Cushion ring rubber
Cutting compounds and other supply materials

5. MATERIAL HANDLING
a—Brought by Trucker from purchased stores department
b—Removed by Operator tends to eleminate monotony by providing for change of work
c—Handled at work station by Operator

6. SET-UP (Accompany description with sketches if necessary)
Carton of handles and carton of rings opened on bench. Operator picks up handle in one hand and ring in the other and forces ring into position
Handle
Ring
a—Tool Equipment
Present Manual operation
Suggestions Provide fixture for holding rings in position while operator forces handle into ring, also necessary bins for parts and assembled pieces.

DETAILS OF ANALYSIS
Can purpose be accomplished better otherwise?
Can opra. being analyzed
be eliminated?
be combined with another?
be performed during idle period of another?
Is sequence of oprns. best possible?
Should oprn. be done in another dept. to save cost of handling?
Are tolerance, allowance, finish and other requirements
necessary?
too costly?
suitable to purpose?
Consider size, suitability, straightness, and condition.
Can cheaper material be substituted?
Should crane, gravity conveyors, totepans, or special trucks be used?
Consider layout with respect to distance moved.
How are dwgs. and tools secured?
Can set-up be improved?
Trial pieces
Machine Adjustments
Tools
Suitable?
Provided?
Ratchet Tools
Power Tools
Spl. Purpose Tools
Jigs, Vises
Special Clamps
Fixtures
Multiple
Duplicate

Methods Engineering Council Form No. 101
ANALYSIS SHEET

FIG. 17.—Analysis sheet (front)

require a more rugged construction and finish to protect them from the rougher usage to which they are subjected.

The time-study man should know when a part being machined is to have a running fit or a driving fit, a contact surface or a

surface merely smoothed up for appearance. He should know the effect that a close or a loose fit will have on the performance of the apparatus. He should know if the operation is prelim-

7. CONSIDER THE FOLLOWING POSSIBILITIES.

1. Install gravity delivery chutes.
2. Use drop delivery.
3. Compare methods if more than one operator is working on same job.
4. Provide correct chair for operator.
5. Improve jigs or fixtures by providing ejectors, quick-acting clamps, etc.
6. Use foot operated mechanisms.
7. Arrange for two handed operation.
8. Arrange tools and parts within normal working area.
9. Change layout to eliminate back tracking and to permit coupling of machines.
10. Utilize all improvements developed for other jobs.

RECOMMENDED ACTION

Suggested to H Reed 4 21 40
Incorporated in design of fixture, 4-22-40
Only one operator
Suggested to foreman 4 20 40
Purchased 4 25 40
Designed 4 22 40
Provided for by fixture
Arrange bins around fixture on bench
No back tracking at present

8. WORKING CONDITIONS

Light satisfactory. Ventilation only fair. Room temperature high because of furnaces nearby. Water fountain within 40 ft
No accident hazards.

a—Other Conditions

All time cards written by time keeper.
An active item.

Light
Heat
Ventilation, Fumes
Drinking Fountains
Wash Rooms
Safety Aspects
Design of Part
Clerical Work Required (to fill out time cards, etc.)
Probability of Delays
Probable Mfg. Quantities

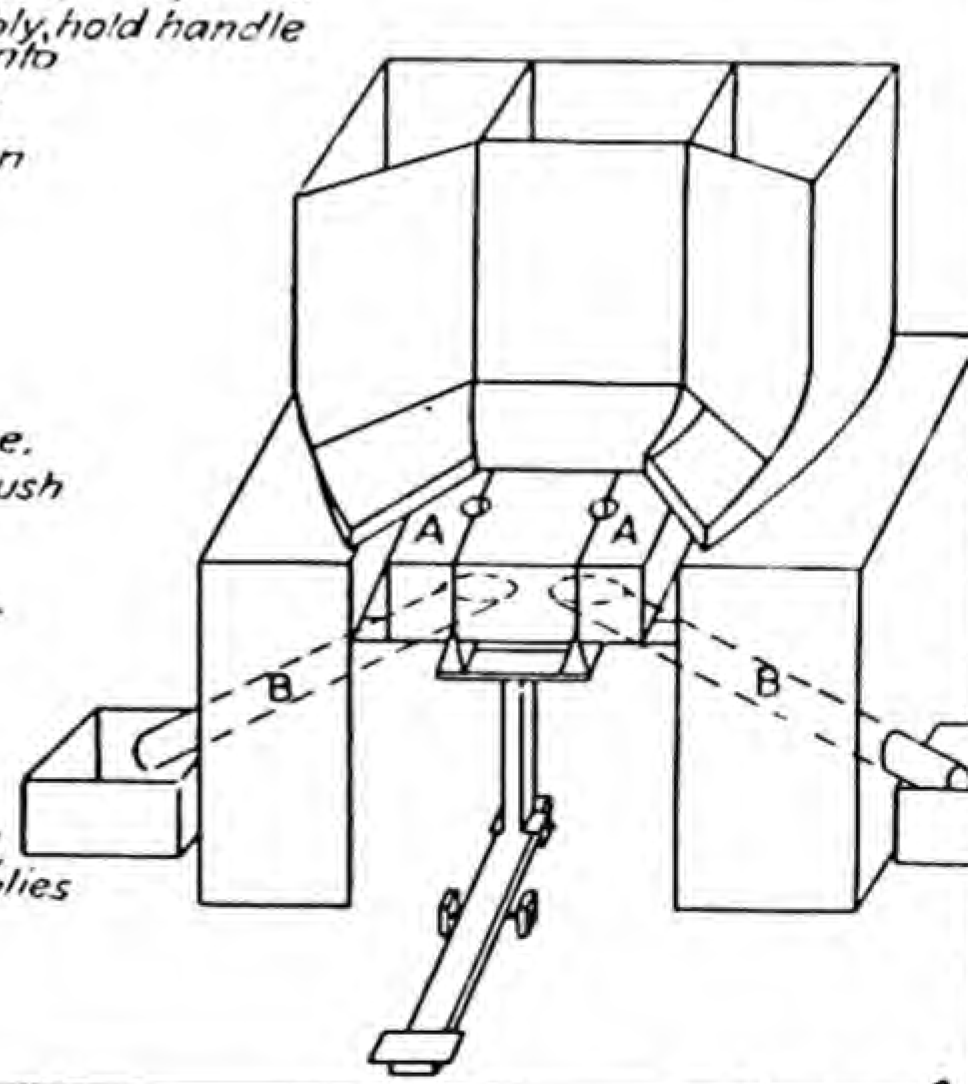
9. METHOD (Accompany with sketches or Process Charts if necessary)

a—Before Analysis and Motion Study

1. Pick up handle (l.h.); pick up ring (r.h.).
2. Position parts for assembly, hold handle in left hand, force ring onto handle with right hand.
3. Toss assembly into carton on bench.

b—After Analysis and Motion Study

1. Slide two rings into fixture.
2. Pick up two handles and push into rings held in position by fixture.
3. Operate foot-release lever while reaching for rings.



Parts "A" move outward when foot lever is operated, thus permitting the assemblies to drop into chutes "B" leading to totepans

Arrangement of Work Area
Placement of
Tools.
Materials.
Supplies.
Working Posture
Does method follow Laws of Motion Economy?
Are lowest classes of movements used?

See Supplementary Report Entitled

Date

OBSERVER *W. C. Powell* .... APPROVED BY *J. B. Johnson* .....

FIG. 18.—Analysis sheet (back).

inary to some other operation, as in the case of a rough turn for a grinding operation. In general, the time-study man should know the reason for every detailed operation being performed and its effect in the ultimate use and success of the product.

Complete Survey of All Operations Performed on Part.—Operation or flow process charts are customarily made in order to survey all of the operations performed on a part in their relation to one another. On some studies, however, it is not considered necessary to use process charts. At the same time, the desirability of viewing the operations in their relation to one another should not be overlooked, and, for this reason, space for this survey is provided on the analysis sheet.

This step of the operation analysis procedure often brings out the fact that the operation under consideration can be performed better in some other way. Perhaps it can, for example, be combined with another operation, or in some cases it may be eliminated altogether by changing certain other operations. Suppose a time-study man is analyzing the milling-machine operation on a small casting. During his survey of the operations performed on the part, he learns that, after milling, the part is taken over to a bench where the burrs left from milling are filed off. Later, during his study, he notices the operator of the milling machine has several minutes while the machine is making the cut during which he has nothing to do. From his survey of all of the operations performed on the part, he sees at once that this operator can do the filing during the idle time, and thus the operation of filing burrs is eliminated as a separate operation. If all of the operations performed on the part had not been considered during operation analysis, this possibility might have passed unnoticed. Where the possibilities for combining operations are not so evident as in the case mentioned, a more detailed study by means of man and machine process charts may be made. The survey of the operations performed on the part, however, will suggest the desirability of drawing up such charts.

Inspection Requirements.—After the time-study man has satisfied himself as to the purpose of the operation and has studied at least briefly all of the other operations performed on the part, he should familiarize himself with the requirements with respect to tolerances, finish, and the like. Usually, these requirements are established by the engineering department, but the time-study man should not accept these blindly. He should view the requirements from his knowledge of the purpose of the operation plus the engineer's specifications, rather than from the specifications alone. Sometimes it will be found that

the engineer has made the tolerances unnecessarily close for the purpose of the finished product. The time-study man should take this up with the engineer, pointing out that the cost will be unnecessarily high if the close tolerances are adhered to, and he should attempt to have a change made. If the time-study man has a curve prepared such as is shown in Fig. 19, it will aid him to get the change made. This curve shows in per cent how the cost increases for fitting operations as the tolerance decreases. A set of such curves to cover all operations such as turning,

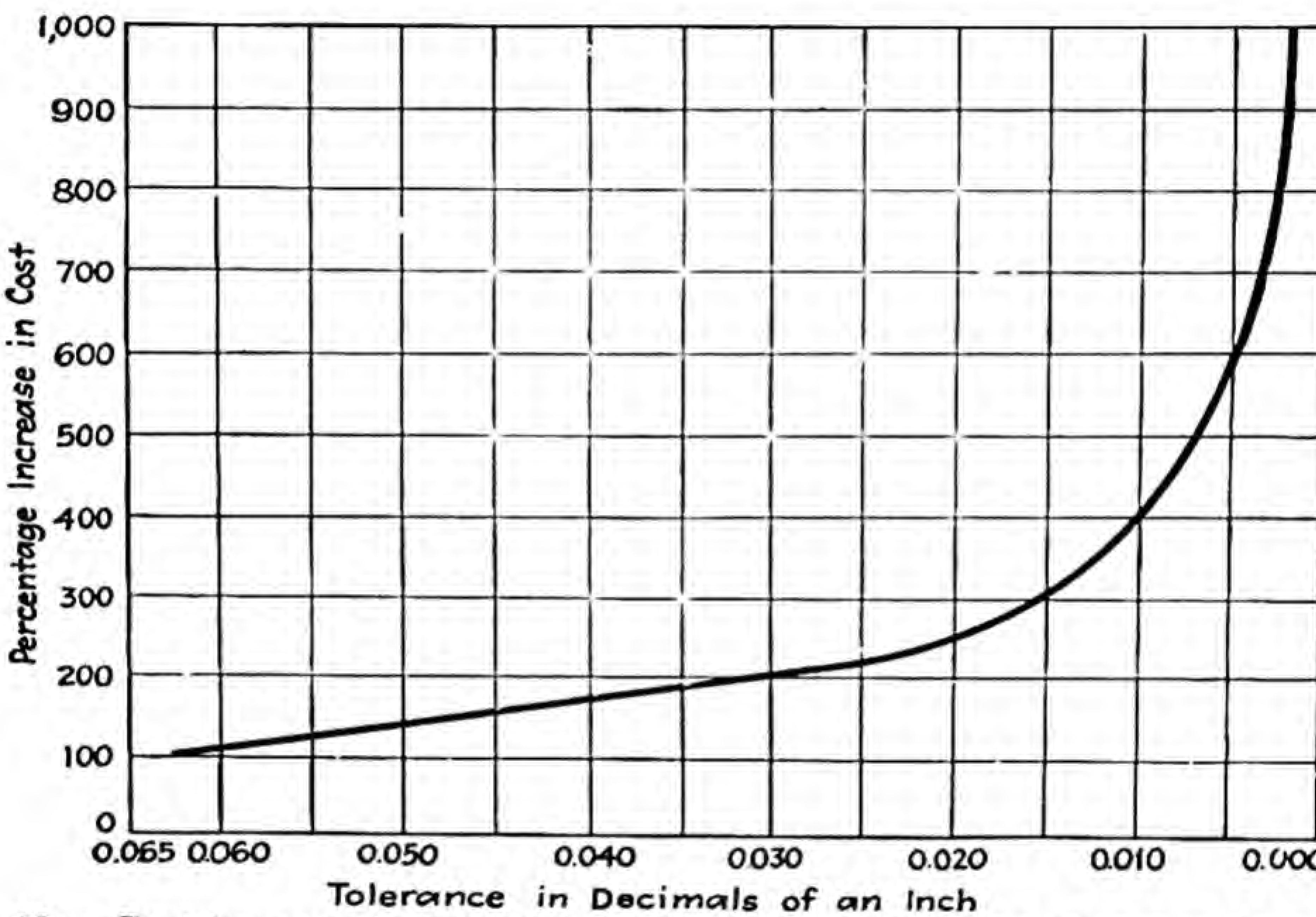


FIG. 19.—Cost increase in per cent for fitting operations as tolerance decreases.

grinding, and the like will serve to illustrate graphically and clearly just how much close tolerances affect cost.

The time-study man should work with the inspector in his consideration of job requirements. The inspector, due to his own intimate knowledge of the purpose of the part, will be able to assist the time-study man in determining whether the tolerances, finish requirements, and so forth are necessary as specified, and he will prove to be a valuable ally in cases where it is necessary to ask the engineer to make a change.

If the piece is to be inspected immediately after the operation has been performed, the time-study man will familiarize himself with such requirements as finish, dimensions, tolerances, and

allowances. If the piece is to have one or more subsequent operations performed on it before reaching the inspector, the time-study man should learn the final requirements. Then, he should study the subsequent operations in order to learn how they fit together as a whole to make up the finished product. He will learn the part played by the particular operation he is about to study in bringing the product toward the finished state.

Knowledge of inspection requirements will also enable the time-study man to be certain that the material or part is delivered to the operator in the proper condition, and that he performs all the necessary, and only the necessary, work upon it.

Material.—All materials should meet required specifications as to physical properties and conditions. All abnormal conditions, such as castings being extra hard or defective due to improper molding or bar metals being oversize, unusually tough, or crooked, should be traced to the cause and an attempt made to bring about a correction. Excess material on castings over that necessary to insure the required finish should be eliminated if practicable from a foundry standpoint. The reason for excess material in any place over that required for the proper making of the part should be traced to the source, and suggestions made to eliminate it. Such a condition not only makes the operation longer without improving the finish of the product, but it also causes a great waste. In the case of castings, it is not uncommon to have to remove $\frac{1}{2}$ inch of material in machining where $\frac{1}{4}$ inch would have made a perfect job with fewer cuts. This same condition may be found in the machining of parts from bar stock, or in making parts in woodworking shops. In fact, it is a condition which may be looked for in almost any line of industry.

In assembly work, punchings, machined parts, molded parts. and parts made by hand should be accurate and according to specifications. It is necessary to keep all fitting, filing, and adjusting down to a minimum in order to insure a better product and a greater output in less time.

Materials such as oil and cutting compounds for machining or sand for molding, which are used in the making of parts or the performing of operations, should be suited to the nature of the work. It is necessary to use a fine sand in making aluminum castings, but it would be wasteful to use this same sand for some brass alloys because of the additional venting that would be involved. In general, anything about the material used in any

operation which causes unnecessary extra work should be determined and corrected before establishing a standard allowance.

Many jobs require the use of nails, glue, nuts, bolts, lock washers, terminal clips, rivets, and other miscellaneous parts that are commonly called indirect materials or supplies. The amount of time which the operator must spend in getting such materials from the storeroom and in placing them in convenient receptacles around his work station must be considered with a view to the later determination of a supply allowance.

Material Handling.—The time-study man must ascertain how the material on which work is to be done is brought to the work station of the operator and how it is removed after the operation has been completed. If the workman has to go for the material himself, he should be allowed time for getting it. Perhaps, in this case, it will be found that so much of the workman's time is spent in getting and removing materials that it will be less expensive to provide a laborer to do this work and thus allow the higher priced operator to spend more of his time in actual productive work.

The means by which the material is transported from place to place should be considered by the time-study man. Material handling is unproductive labor and should be reduced to a minimum. Many ingenious devices may be made to fit special conditions. Specially designed racks or bins, moved from place to place by lift trucks, may be helpful in handling delicate or highly finished work to keep it from being injured through contact with like parts. Again, it may be found advisable to change the layout of several work stations so that material may be passed from one operator to another by conveyors. In this case, gravity should be used as the conveying power wherever possible, because of the advantage of initial low cost and low maintenance charges that such systems enjoy. Figure 20 illustrates an installation of this kind.

In putting a storeroom on an incentive basis, the analysis of material handling becomes of paramount importance. Here, outside of a little clerical work, material handling is the only job done. Counting devices, adjustable-partition tote pans, special racks, and the like may be designed to suit each case.

Handling devices which may aid the performance of the operation, such as the one shown by Fig. 21, should be utilized wherever savings can be effected. Jib cranes are often essential

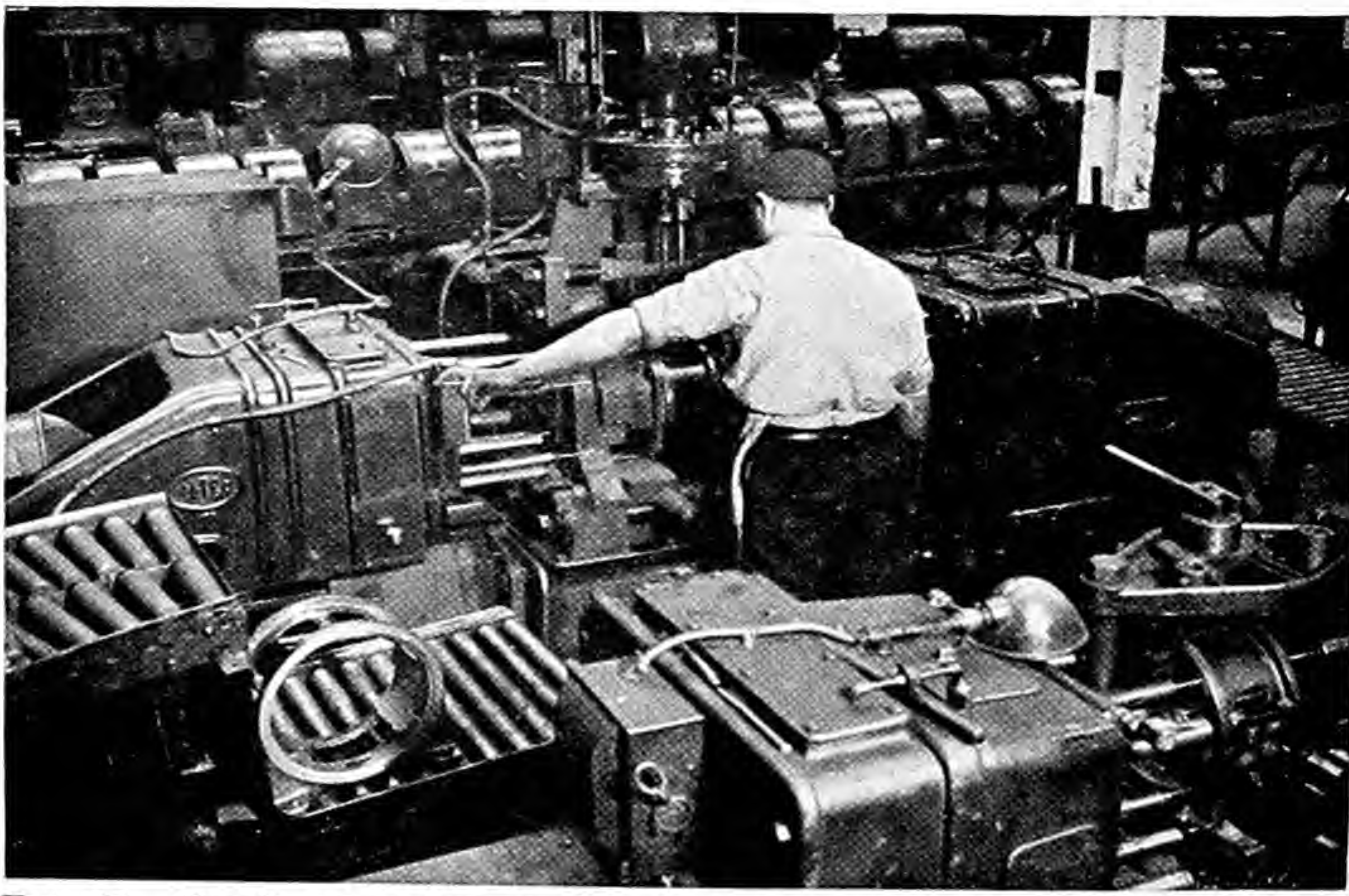


FIG. 20.—Gravity conveyors used to move material to and from machining operation.

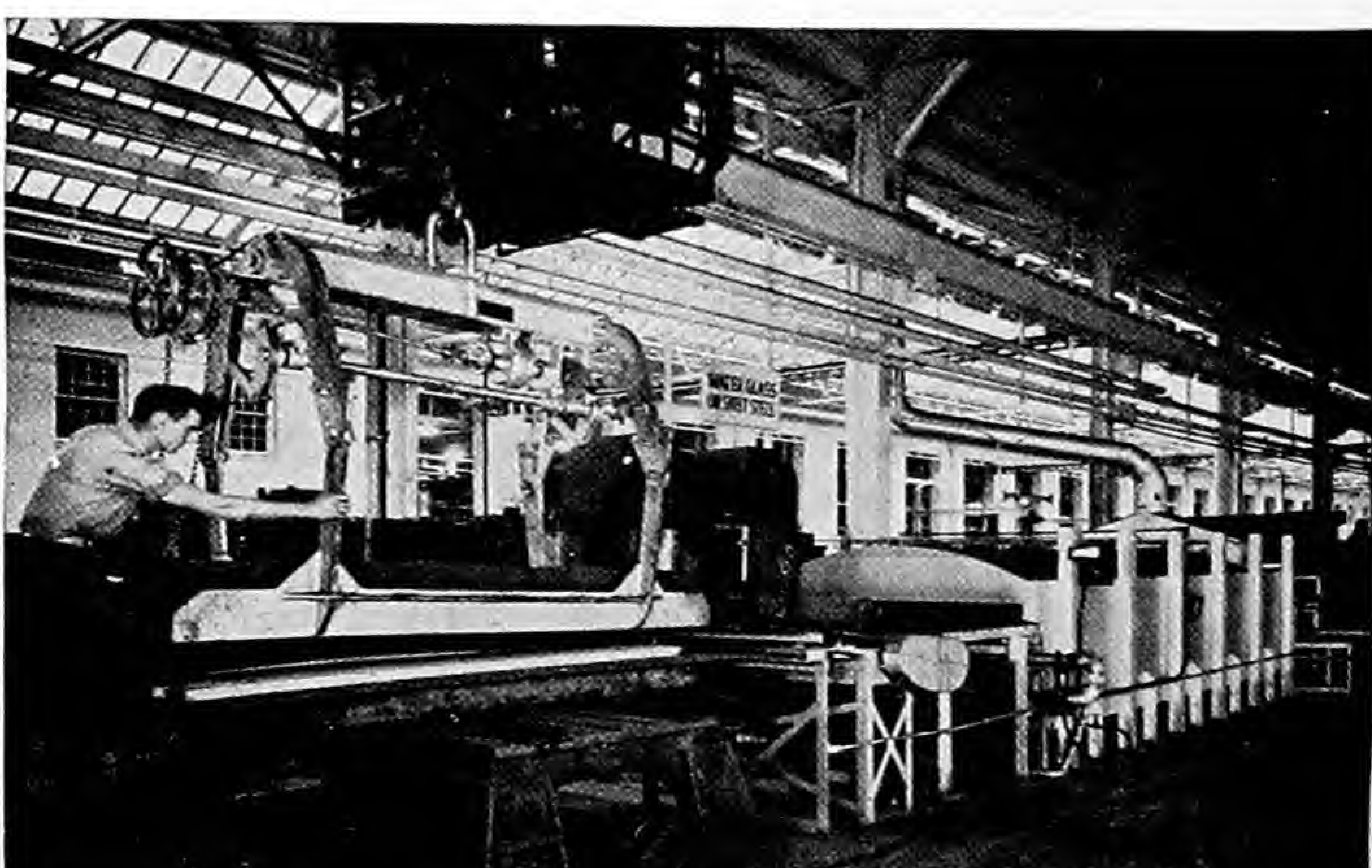


FIG. 21.—Special handling device used for handling sheet steel at coating process.

near machines handling large, heavy parts. Gravity-fed chutes, from which supplies may be quickly extracted, a given number at a time, may be utilized to facilitate handling on bench operations. Chutes fed by overhead conveyors save a molder much time in filling his flask with sand.

Set-up and Tool Equipment.—All tools should be the most efficient available for any given operation. An operator should not be permitted to perform an operation by hand that can be done better and in less time on a machine. He should not use a smooth file when a rough one would do just as well, for with a rough file he will accomplish more work with less expenditure of energy. Files, chisels, saws, and the like should not be used after they have become dull. They should either be exchanged or sharpened, as they cause hard work with little actual accomplishment. Hammers should be of proper style and weight for the purpose, and layout tools should be in good condition and suitable to the work.

Special labor-saving hand tools should be used whenever a saving in time would result. Examples of these are socket wrenches, ratchet wrenches and screwdrivers, air drills, air hammers, air chippers, and air rammers. A striking example of what can be accomplished by the use of special hand tools occurred in the operation of mounting a piece of apparatus on skids preparatory to crating for shipment. Four bolts were used in mounting, and in running on the nuts an open-end wrench was formerly used. It was impossible to make a complete circle due to obstructions. The workman had to make a part turn, take a new hold, and repeat this until the nut was tightened. The substitution of a ratchet wrench for the open-end wrench reduced the time for the mounting operation by about 60 per cent.

Cutting tools used on machines should be properly ground and should have the correct clearances and shapes. Machine tools and all driving equipment and belts should be in good repair. The time-study man should determine whether or not the work is being done on the machine best suited to the job being studied. No job should be done on a No. 1 milling machine that could be done better and faster on a No. 4 milling machine, nor should a job be finished on a milling machine, lathe, or boring mill that could be worked to advantage on a grinder, or vice versa. An engine-lathe job should not be done on a turret lathe, nor a turret-lathe job on an engine lathe. In analyzing the tools

used on a job, the time-study man may find that the operation could be segregated to advantage, *i.e.*, part of it could be done on one machine and part on another with a resultant saving in time.

For example, in the machining of cast-iron bushings, the elements of the inside and the outside surfaces must be parallel. It is very hard to get this condition on a turret lathe. Nearly true surfaces may be got if the set-up is carefully made by an expert, but even then there will be some variation between the individual pieces, and the results will be neither dependable nor satisfactory. For these reasons, it was formerly held that the job could be done only on an engine lathe. A time-study man, in analyzing this job preparatory to making a time study, believed that the rough and finish boring and the rough turning could be done on a turret lathe. Then, by mounting the bushing on a mandrel, the finish turn could be made accurately on an engine lathe. This was tried successfully, and a 45 per cent reduction in machining time resulted.

An operation done on a bench by hand can sometimes be partly done to advantage on a machine. Riveting is sometimes done on a bench when a saving in time and an improvement in appearance might be effected by upsetting the rivets with a hammer just enough to hold them in place and then finishing the job on a rivet spinner.

Wherever the quantity warrants, special jigs and fixtures should be used, as they effect a great saving in time and assure more accurate and uniform work. Multiple jigs and fixtures, *i.e.*, those made to hold several pieces, should be applied whenever it would be an advantage to do so. Indexing and rotary fixtures should be used in machining operations wherever possible, as they very often make it possible to reduce the time for performing an operation to the time required to remove and place the part to be machined. Self-centering devices on lathe operations should be used where practicable. Often, it will be found to be advantageous to secure two fixtures where it is necessary to remove the fixture to reload it. The operator can then load one while the cut is being made on the other.

The time-study man should continually try to effect savings by the elimination of elements of the operation through the application of specially designed fixtures. To give an example of what can be accomplished by the application of special fixtures, a

job that was formerly ground on a plane surface grinder was held in a vise during the operation. It was suggested that a multiple fixture be made so that the job could be done on a Blanchard grinder. Accordingly, a fixture to hold 20 pieces was designed and made. The work was transferred to the Blanchard grinder, and a saving of 80 per cent in time was made.

In the operation of "point and face under head" in making machine bolts, an element of the operation was made unnecessary by a somewhat different type of fixture. The bolts, during the machining operation, are held and driven by a socket held in a chuck. Formerly when the bolt was finished, the operator,

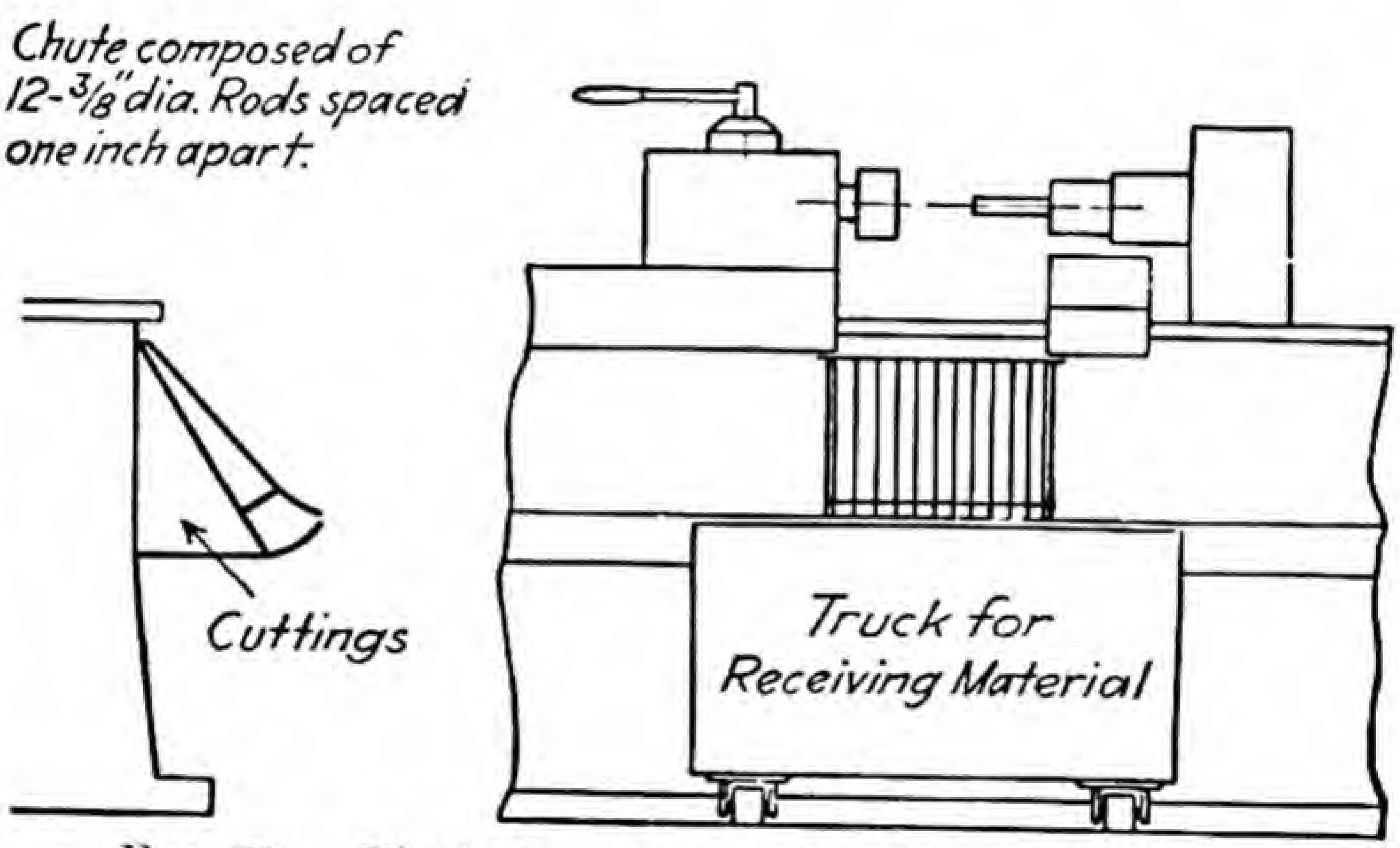


FIG. 22.—Chute for separating bolts and cuttings.

without stopping the machine, knocked it out of the socket, and it fell, together with the cuttings, into the pan of the machine. This made it necessary for the operator to stop work periodically to separate the bolts from the cuttings. A simple chute shown in Fig. 22 was designed and attached to the machine. This chute, a grating of parallel bars, guides the bolts into a box truck and allows only the cuttings to fall through into the pan. The time formerly spent in the separating operation is thus given to machining which, of course, brings about an increase in production at a reduction in cost.

When an operation is to be performed on a bench, special attention should be given to the location and arrangement of the bench. The design of the bench is often important. A bench is usually considered to be merely a table of indefinite length, about 3½ feet high and about 3 feet wide. In the majority of

cases, this type of bench answers the purpose very well, but in some special instances, the bench may be designed especially for a certain class of work with a saving of time and effort. For example, where it is necessary to glue flakes of mica together to form a large sheet, the workbench should be tilted on an angle so that the operator may be able to see and reach all parts of the bench easily. In addition, the bench may be made of translucent glass beneath which a light is placed, thus enabling the operator to see easily any bare or thin spots in the mica sheet. This bench not only saves time but also raises the quality of the sheets, for it is almost impossible for a flaw to exist undetected.

Vises particularly suited to the work at hand should be conveniently placed on the workbench. The wrong type of vise for a given job may greatly slow up an operation. For instance, a workman may have some hard straightening to do and only a light vise with which to hold the part. He will have to exert a considerable effort to tighten the vise enough to hold the piece, and even then when he is hammering on or bending the part, it may come loose from the vise causing a loss of time and often bruised knuckles or toes. A heavier, larger vise here will do away with this trouble.

Surface plates should be used on benches where there is any heavy hammering or riveting to do. Having something solid upon which to lay the part will greatly facilitate these and similar operations.

All materials and supplies should be arranged in the most convenient manner possible, so that the operator loses no time in needless hunting. Supplies should be placed where wanted within easy reach of the operator. The bench should be clean and orderly.

Common Possibilities for Job Improvement.—The operation analysis up to this point will usually bring to light a number of possibilities for improving methods. Among the various things which may be done to improve methods, there are ten which are sufficiently important to justify separate consideration. Experience has shown that one or more of these ten common possibilities for improvement can be applied to practically every job studied. The possibilities are listed under Item 7 on the back of the analysis sheet and are as follows:

1. Install gravity delivery chutes.
2. Use drop delivery.

3. Compare methods if more than one operator is working on same job.
4. Provide correct chair for operator.
5. Improve jigs or fixtures by providing ejectors, quick-acting clamps, etc.
6. Use foot-operated mechanisms.
7. Arrange for two-handed operation.
8. Arrange tools and parts within normal working area.
9. Change layout to eliminate back-tracking and to permit coupling of machines.
10. Utilize all improvements developed for other jobs.

Gravity delivery chutes are useful in bringing material to the point of use or taking it away from the point of use after

FIG. 23.—Drop delivery of finished piece through hole to container as hand reaches for next piece.

the job has been done. Such chutes are usually quite simple to make, and often the time-study man can make one himself by bending up a piece of sheet metal and attaching it in the proper location during the course of his study.

Drop delivery is the term used to express the thought of using gravity as a means of moving material or tools, usually away from the point of use. A common application consists of dropping the finished piece into a container as the hand reaches for

the next piece to be worked upon, as shown in Fig. 23. Where gravity can not be utilized, the same effect can sometimes be obtained by attaching the tool or other object to be disposed of to a cord running over a pulley and attached to a counterweight or to a spring-wound reel, as shown in Fig. 24. When drop delivery is used, the motions required to dispose of tools or material are reduced to a minimum.

FIG. 24.—Drop delivery principle may be obtained with springs or counterweights.

Probably the most important part in the performance of any job is the method, and it is in this part of the analysis that the real worth of the time-study man will be revealed. It is usually found that where time study is not used, each individual does his own work according to his own ideas and, in most cases, never stops to consider whether or not the method can be improved upon, being satisfied with the fact that the finished product meets requirements. The argument is often advanced that every person has his own way of doing things and that it matters not how a job is done as long as it is done. It is abso-

lutely true that people have their individual peculiarities and ideas, but this is no argument against the advantages to be derived from standardized methods.

It is not uncommon, where more than one workman is engaged on a given operation, to find a difference in output which is often as much as 100 per cent. This is generally believed to be due to a difference in ability. Of course, this is partly true, but not to the extent that it is thought to be. A thorough analysis will often show that different methods are being used and that the operators who are turning out the greater production are not expending so much energy as those turning out the lesser production. The former work with their heads as well as their hands and consequently have developed a smooth systematic method. It is altogether possible to instruct the less efficient operator to follow the same method, thereby increasing his output to such an extent that the greater part of the difference between the operator having the higher efficiency and the one having the lower efficiency is eliminated.

It is not to be expected that the time-study man, by observing the different operators engaged on the same class of work, will find one who is perfect whom he may use as a standard by which to judge and instruct the others. He will, however, find that in many cases one operator will have developed a method for doing a certain element of the operation which is easier and faster than the method used by his fellow workers. One of the other operators may have perfected a different element of the operation, and so on. By discovering these differences through analysis, the time-study man is able to combine the best methods for doing each element into one standard method for doing the whole operation.

In some plants, there is a decided preference for having workers work standing rather than seated. The feeling probably is that a more businesslike appearance results. This may be so, but fatigue studies show that this is not the best means for securing maximum production. Laboratory studies of hourly metabolic rate or the total heat dissipated in the course of a working period indicate that it requires somewhat more than 20 per cent more energy to do light work standing than to do the same type of work seated. Therefore, whenever it is possible for an operator to work seated, the time-study man should recommend that this be done.

In providing chairs for industrial workers, attention should be given to the type of chair used. The most satisfactory for general purposes consists of a chair of adjustable height, with an adjustable backrest. The seat itself should be wide from side to side but comparatively narrow from front to back. If the chair is adjusted so that the operator's feet cannot touch the floor, a footrest should be provided.

Jigs and fixtures can often be designed to permit quick loading and unloading. One example of this is a box jig with an ejector which operates in conjunction with the cover. When the cover

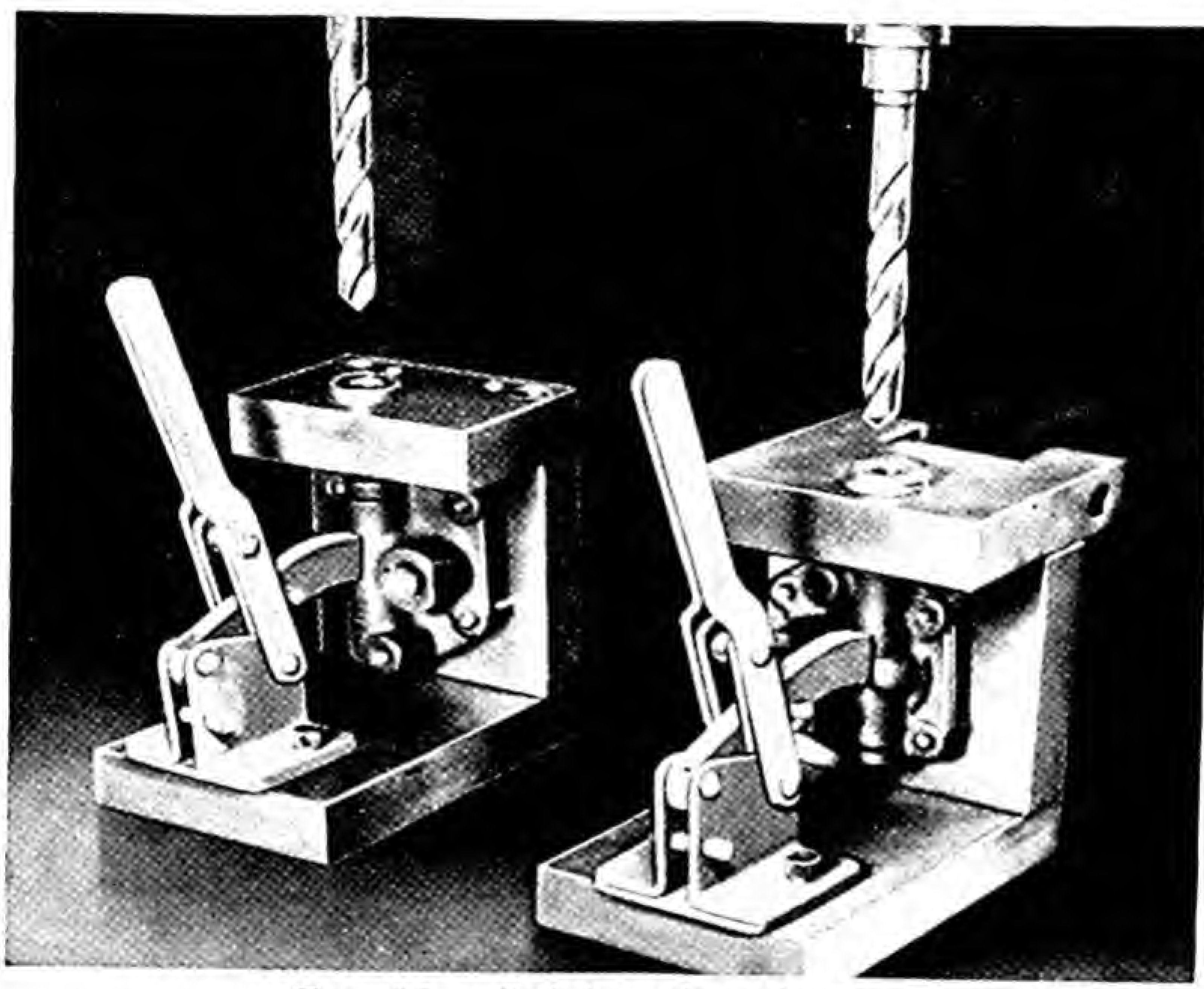


FIG. 25.—Quick-acting clamps.

of the box jig is opened, the ejector pushes the part out of the jig. Quick-acting clamps of the type shown by Fig. 25 are most useful in connection with work which must be clamped in a jig or fixture. They are used quite extensively for welding operations on large sheet-metal work.

Foot-operated mechanisms are useful if by employing them the hand can be freed to do other work. Foot-operated drill presses are becoming quite common in industry, and the same principle may be extended to the operation of vises, clamps, ejectors, light arbor presses, and the like.

Two-handed operation is a term used to describe the set-up where the operator is able to work with two hands moving

simultaneously over symmetrical paths in opposite directions. This is an effective method of working, and it will be discussed at greater length in Chap. VIII.

Normal and maximum working areas are also described in detail in Chap. VIII. It is important to keep in mind the principles illustrated by Fig. 43 when analyzing an operation, in order that tools and materials will be arranged so that they can be grasped with the shortest and least fatiguing motions.

Proper plant layout plays a material part in efficient operation. Hence, the layout should receive at least passing consideration during the course of an operation analysis. Layout studies usually cover a more comprehensive field than that dealt with by the analysis of a single operation, but if during the course of an operation analysis a poor layout is uncovered, a further study may be justified. The possibility of machine coupling occurs wherever machining under power feed is done. During that time, the operator usually has nothing else to do, and the possibility of giving him one or more additional machines to run should be considered. As has already been pointed out, man and machine process charts are a valuable aid in studies of this kind.

Where operation analysis is made a part of the regular factory procedure, methods improvements are certain to result. When an improvement is made on one job, the possibility of applying it to other similar jobs should always be considered. Most methods improvements are based upon the application of certain fundamental principles, and if these principles are recognized, their further application may be made.

Working Conditions.—The conditions under which the work must be performed should be carefully studied. There are two general types of conditions: namely, those which affect the operation through the operator, and those which affect the operation directly. Both kinds of conditions should receive study.

The first type of working conditions includes any condition which might affect the mind or health of an operator, thereby interfering with the efficient performance of the operation. It is recognized that although it is possible to turn out work under unfavorable conditions, much better results are obtained if conditions which are satisfactory from the viewpoint of the worker are maintained. Temperature, for example, is an important consideration. The most favorable temperature for comfort and efficiency is 65 to 70°F., and this should be maintained the year

around as closely as possible. In many places, such as around furnaces or near solder pots, it is nearly impossible to maintain the ideal temperature. Fans or some other kind of forced draft may be used to advantage to keep the air circulating, but in most cases the temperature will be variable. An allowance for such conditions must be made when considering the effort an operator will be able to give throughout the day. The same holds true when the temperature falls below the ideal, as in unheated warehouses in winter and around refrigerating lines.

Ventilation should be adequate to provide sufficient fresh air at all times. In ordinary work places, such as machine shops or assembly rooms, it is usually easy to insure this through proper arrangement of windows, fans, and ventilators. In many places, however, the matter of proper ventilation offers a serious problem. Acid fumes, dust, and the like must be removed by specially constructed suction devices. Paint shops and dip rooms often abound in unpleasant smells which, while not actually injurious, are irritating and may cause headaches. An operator cannot be expected to do his best work under such conditions, and if the conditions cannot be corrected, extra allowances must be made.

Daylight is preferable to artificial light and should be utilized wherever possible. Eyestrain due to poor light should always be guarded against. A man cannot turn out accurate work if he cannot read his scales and verniers with ease. He cannot work at his greatest capacity if he is not able to see exactly what he is doing.

There should be discipline with a feeling of freedom and cooperation between the supervisors and the workmen, and a mutual respect and interest for one another's duties, problems, and responsibilities. In general, the entire surroundings and atmosphere should be mutually beneficial, pleasant, and healthful.

Among the conditions affecting the operation are the minor or indirect operations which partly determine the success with which the repetitive work may be done. For example, there is a certain amount of maintenance work which must be performed by the operator of a machine. He must oil and clean his machine daily, and he should devote a certain amount of time to a general cleanup of his work station at regular intervals. The time-study man must analyze this work and determine just how much of it is necessary. This he must do so that he may later make a proper allowance for the time expended.

In many other fields, there is some necessary work which must be similarly handled, although it is not maintenance in the strict sense of the word. The time spent in a foundry in wetting and mixing a supply of molding sand when it has dried out over a week-end cannot be charged directly to any one production job, but it is entirely necessary, and due allowance must be made. Where a blacksmith must start his own fire each morning and maintain that fire throughout the day, allowance must be made for time so spent.

The Questioning Attitude.—In conducting an operation analysis, the questioning attitude should be assumed toward everything connected with the job. Nothing should be taken for granted just because it exists at the time the study is made, but the necessity for every factor which surrounds the job should be given careful consideration. Unless this questioning attitude is consciously maintained, the making of operation analyses may become perfunctory, and the results which are obtained will be correspondingly less.

The questions which the analyst asks either of himself or of those who are in some way connected with the work may be framed mentally at the time the analysis is made, or a check list may be made up of questions which are to be asked on every operation study. Both methods possess advantages and disadvantages. If questions are asked only as they occur to the analyst, important points may be overlooked. At the same time, the questions which are asked will have a direct bearing on the operation under study and hence will be answered carefully. If a check list is used, there is the danger that through frequent use a perfunctory attitude will be assumed toward it. Many of the questions on such a list will not apply to the particular operation under consideration, and there is then the danger of assuming that there are more questions which are not applicable than actually is the case. It often requires considerable ingenuity to see just how certain questions do apply to the work at hand, and if this ingenuity is not exercised, opportunities for improvements are likely to be passed by. At the same time, a written check list gives a systematic procedure to follow and insures that all questions of major importance will at least be asked.

The following is a list of typical questions which might be asked at each step of an operation analysis. It is by no means complete, but indicates the type of questions which should be asked.

Purpose of Operation

1. What is the purpose of the operation?
2. Is the result accomplished by the operation necessary?
3. Was the operation established to correct a condition that has since been corrected otherwise?
4. Can the purpose of the operation be accomplished better in any other way?
5. Can the supplier of the material perform the operation more economically?

Complete Survey of All Operations Performed on Part

1. Can the operation being analyzed be eliminated by changing the procedure or the operation?
2. Can it be combined with another operation?
3. Can it be subdivided and the various parts added to other operations?
4. Can the operation being analyzed be performed during the idle period of another operation?
5. Is the sequence of operations the best possible?

Inspection Requirements

1. What are the inspection requirements of this operation?
2. Will changing the requirements of a previous operation make this operation easier to perform?
3. Are tolerance, allowance, finish, and other requirements necessary?
4. Are they suitable for the purpose the part has to play in the finished product?
5. Can the requirements be raised to improve quality without increasing cost?

Material

1. Does the material specified appear suitable for the purpose for which it is to be used?
2. Could a less expensive material be substituted that would function as well?
3. Is the material furnished in suitable condition for use?
4. Is material ordered in amounts and sizes that permit its utilization with a minimum amount of waste, scrap, or short ends?
5. Is material utilized to the best advantage during processing?

Material Handling

1. Where should incoming and outgoing material be located with respect to the work station?
2. Is a conveyor justified?
3. Can a progressive assembly line be set up?
4. Is the size of the material container suitable for the amount of material transported?
5. Should the material-handling problem in general receive more intensive study in the immediate future?

Set-up

1. How are instructions imparted to the operator?
2. What possibilities for delays occur at drawing room, toolroom, storeroom, or time clerk's office?
3. Is the machine set up properly?
4. Does the workplace layout conform to the principles that govern effective workplace layouts?
5. How is material supply replenished?

Tool Equipment

1. Is the machine tool best suited to the performance of the operation of all tools available?
2. Can the work be held in the machine by other means to better advantage?
3. Should a multiple fixture be provided?
4. Are tools properly ground?
5. Is the necessary accuracy readily obtainable with tool and fixture equipment available?

Working Conditions

1. Is light ample and sufficient at all times?
2. Is proper temperature for maximum comfort provided at all times?
3. Is ventilation good?
4. Have safety factors received due consideration?
5. Does plant present neat, orderly appearance at all times?

Other Conditions

1. Is there a definite check between pieces completed and pieces paid for?
2. Is the design of the part suitable to good manufacturing practices?
3. What clerical work is required from the operator to fill out time cards, material requisitions, and the like?
4. What is the economic lot size for the job being analyzed?
5. Are new men properly introduced to their surroundings, and are sufficient instructions given them?

General questions of the type given above or specific questions covering conditions within a given department or industry may be added to the above list to provide a more complete set of questions.[1]

Method.—All of the operation analysis work described up to the present time is made for the purpose of improving the method. Before the analysis can be considered to be complete, however, a still more detailed type of study should be made during which every motion made by the worker is considered in detail. This secondary analysis of the motions used for doing the work is known as motion study, and it will be described in some detail in the ensuing chapters.

[1] For a more complete discussion of the questioning attitude, see Maynard and Stegemerten, *op. cit.*

CHAPTER VII

THE BASIC DIVISIONS OF ACCOMPLISHMENT

Motion study lies between operation analysis and time study in chronological sequence and is closely associated with both. It employs a different viewpoint from either in looking at an operation and is in most cases the best technique to employ for approaching the best method of doing work. During operation analysis, certain factors of major importance are considered. The purpose of the operation is questioned, its relation to the other operations of the process is considered, and material, material handling, tool equipment, and so on are studied. Finally, as a result of all this, unnecessary work is eliminated, and the remainder constitutes the method as improved up to this point.

Still further improvement can often be effected by bringing to bear a still more detailed type of analysis known as motion study. Operation analysis is a primary analysis which eliminates the major inefficiencies. Motion study is a secondary analysis which refines the method still further. Motion study may and often does suggest further improvements in the factors considered during operation analysis, such as tools, material handling, design, and workplace layouts. In addition, it studies the human factors as well as the mechanical and sets up operations in conformance with the limitations, both physical and psychological, of those who must perform them.

Work Simplification.—A term often used to describe both operation analysis and motion study is "work simplification." The term is descriptive of the aim of these procedures and hence is of practical value in increasing the understanding of the purpose of this work.

When a job is analyzed and motion studied, the objective is to make the job easier to perform. Useless motions are eliminated, and long motions are shortened. As a result, the job is made simple. One of the characteristics of a method established by motion study is that it appears simple and easy to understand.

Development of Motion Study.—Lillian M. Gilbreth and the late Frank B. Gilbreth concentrated intensively on the study of motions, and to them and to the Gilbreth Research Group is due the credit of discovering, recognizing, and expressing the laws of motion which are generally accepted today as being fundamental. They also developed the motion-picture technique for making motion studies which aided inestimably in discovering these laws and which may be used to good advantage in making motion studies under certain conditions. They, more than anyone else, succeeded in impressing on industry in general the importance of a minute study of motions to the end that unnecessary motions be eliminated, production increased, fatigue reduced, and the discovery of and the instruction of the workers in the best way of doing a given operation facilitated.

After a detailed study of many kinds of work and operations, Mr. Gilbreth was led to the conviction that all hand motions should be classified under a relatively small number of fundamental elements. These fundamental elements are known as "therbligs," the word "Gilbreth" reversed, and may be defined as the basic divisions of accomplishment.

Field of Motion Study.—An attempt is sometimes made to distinguish between various types of motion study by referring to what might be called "mental motion study" made by analysis and observation as motion study and to a more refined study made with the aid of motion pictures as micromotion study. In practice, however, this attempt at differentiation appears to add confusion and to accomplish no useful purpose. All motion study work rests upon an understanding of the therbligs or basic operations, and whether these are studied by observation or by motion pictures depends upon the nature of the work at hand. In the pages that follow, therefore, the term motion study will be used to signify the study of all basic divisions of accomplishment used for doing an operation in order to determine the best method for doing it.

When motion study is defined in this way, there is no need for limiting the field to which it applies. This is definitely advantageous. Too often motion study is thought not to be applicable to large or non-repetitive work, and therefore existing methods are accepted as being proper, the work being time studied as it is being performed. On the other hand, if motion study is made a

part of every operation study, the method will receive its share of attention.

The degree of refinement into which it is profitable to go will depend upon the nature of the work and the amount of labor which is involved. It is safe to say that the tendency is to study in too little detail rather than too much. If inefficiencies are not obvious at first glance, it is too often assumed that the work is being done properly and that it will not pay to make a detailed study. As a matter of fact, however, it is in cases of this kind that detailed study is of the greatest value, for without it, improvements would not be made.

Basic Divisions of Accomplishment.—The foundation upon which the motion study technique rests is the concept of therbligs or basic divisions of accomplishment. These are the basic operations used in varying sequence and combinations by means of which all operations are performed. It is essential, therefore, that the time-study man should have a clear understanding of each basic operation. He should be able to recognize the basic operations when he sees them. Certain basic operations are considered to be more effective than others, and by recognizing the ineffective operations, the time-study man finds a starting point for methods improvement through their elimination.

The following is a list of the basic divisions of accomplishment:

Purely Physical Basic Divisions	
Transport empty	TE
Transport loaded	TL
Change direction	CD
Grasp	G
Hold	H
Release load	R
Pre-position	PP
Semi-mental Basic Divisions	
Position	P
Search	S
Select	SE
Mental Basic Divisions	
Plan	PL
Inspect	I
Objective Basic Divisions	
Use	U
Assemble	A

DELAY BASIC DIVISIONS

Avoidable delay	AD
Unavoidable delay	UD
Rest to overcome fatigue	F
Balancing delay	BD

This list is based upon the original list of the Gilbreths, although it varies somewhat in number and arrangement. The basic operation, find, has been omitted. Even in detailed film analysis work, it has been impossible to tell where search ends and find begins, or where find ends and select begins, so although undoubtedly a find does occur between search and select, there appears to be no practical advantage in recognizing it. The original therblig, disassemble, is merely assemble in reverse, and since the same types of movement are involved in each, the two have been combined into assemble.

When the element of time is added to the basic operation concept, two inefficiencies show up which were not covered by the original list. These are expressed by the basic operations of change direction and balancing delay, which will be defined presently. In addition to these, the operation, hold, has been included. These changes are partly due to the redefinition of the original therblig meanings as use over a period of time has indicated that greater clarity could be secured by so doing.

In order further to assist in obtaining an understanding of the meaning of the basic operations, they have been classified into five groups. This classification indicates in a general way the nature of each basic division of accomplishment. Letter symbols are used as abbreviations for the name of each basic operation. These facilitate reference to the basic operations and may be reproduced on charts by typewriter.

Definitions and Explanations of Basic Divisions of Accomplishment.—The exact nature of each basic operation has been interpreted differently by different writers on the subject. In some cases, interpretation has been made to cover major operations such as using transport loaded to cover the operation of moving material with an electric crane. This is useful on certain types of large work. In by far the majority of cases, however, the basic division of accomplishment concept is applied to the things done by the hands of the operators. To avoid confusion, therefore, the following definitions are based largely upon this application. The definitions cover the concepts which have been

found to have the greatest practical value in suggesting methods improvements.

Transport empty is the basic operation employed to move a transporting device unresisted and without load. The transporting device is usually the hand or an object held in the hand

FIG. 26.—Transport empty (right hand).

The motion starts at the instant the hand begins to leave one point or object and ends at the instant the hand reaches or touches the point or object toward which it is moving. Figure 26 shows the empty hand of the operator moving toward the part which is needed next in the assembly she is making. This is a common form of transport empty.

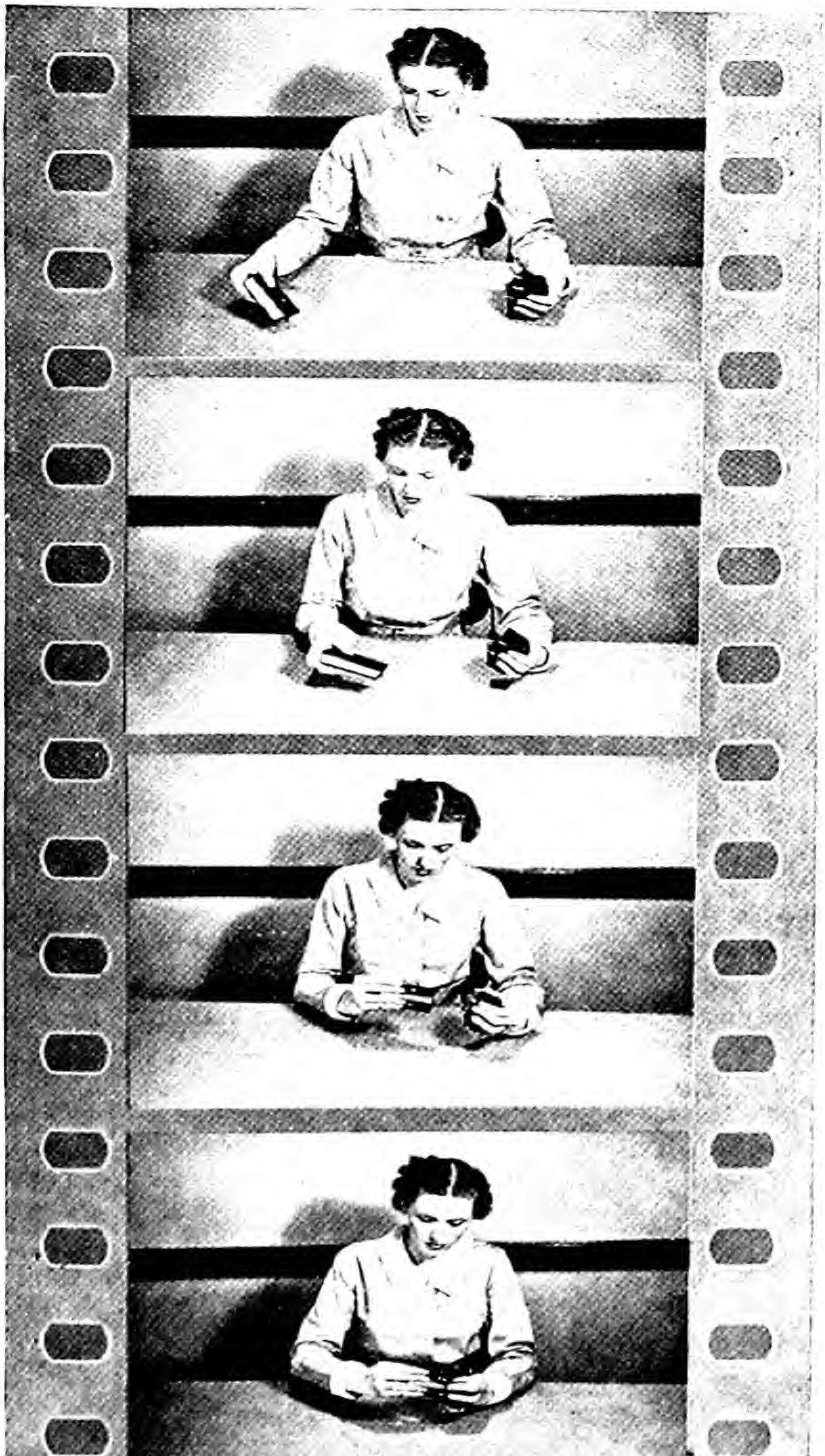


FIG. 27.—Transport loaded (right hand).

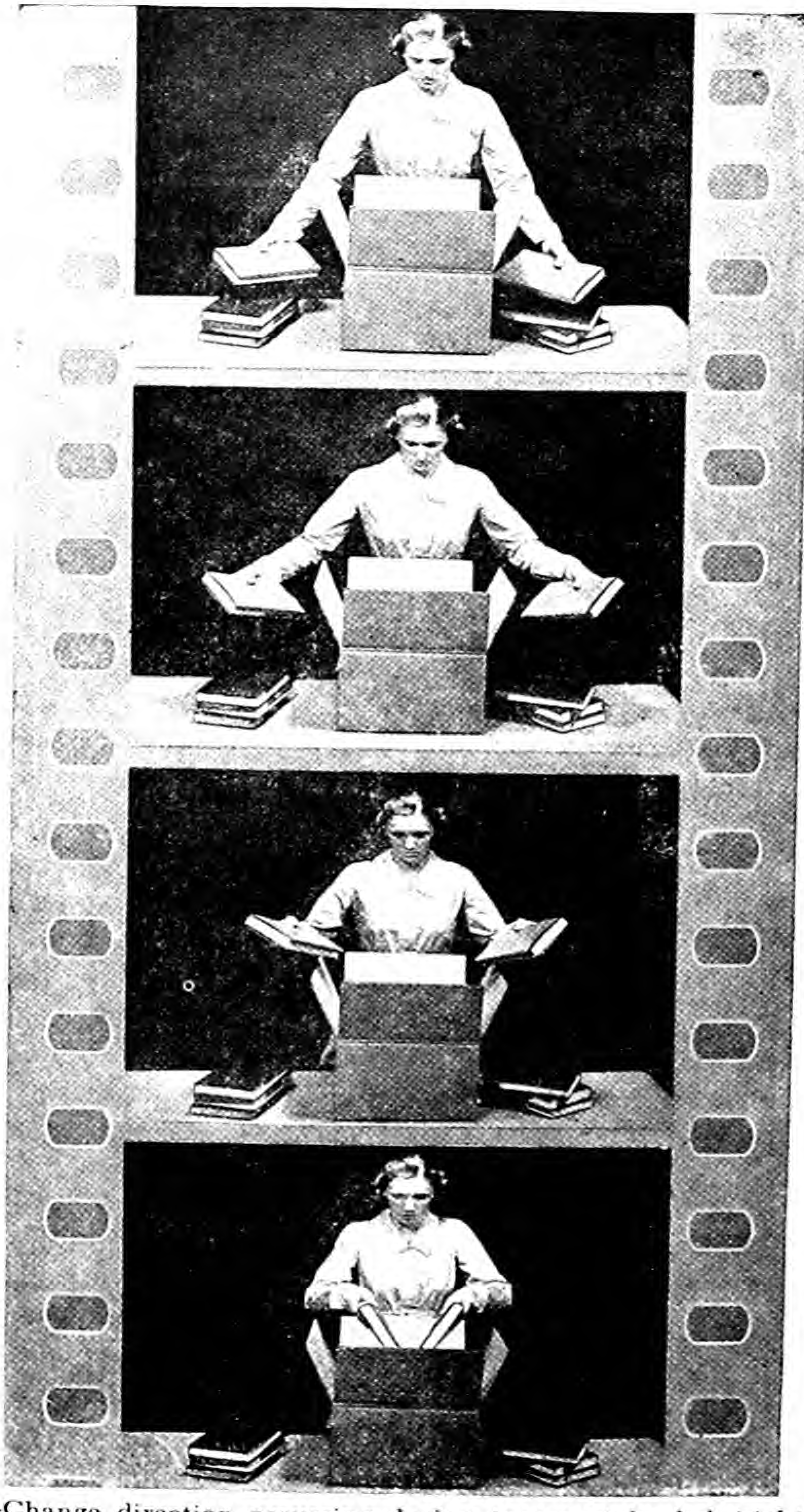


FIG. 28.—Change direction occurring during transport loaded (right and left hands).

Transport loaded is the basic operation employed to move a transporting device loaded or against resistance. An object is moved from one location to another by the hand or by an object held in the hand, or in a broader sense by a truck, a conveyor, or other means. Figure 27 shows the right hand moving loaded with the part to the apparatus which the operator is engaged in assembling. The distance covered during all transport motions should be reduced to a minimum but, more important, the number of transport motions themselves should be kept as small as possible. Small objects are usually best moved by hand, while large, heavy objects call for the use of some auxiliary mode of transportation. If there is much transporting to be done along the same path, the advisability of installing a conveyor should be considered. Chutes leading from an unfinished material supply to a convenient point at the work place and from a convenient point at the work place to the finished material container will aid materially in reducing transport motions.

Change direction is the basic operation employed to change the line or plane along which a transport motion is made. It should be recognized when it occurs, because it requires more time to make a motion of a given length when a change direction occurs than when the motion is made over a normal path. The change direction occurs when it is necessary to move around an obstructing object as shown in Fig. 28. Here the operator is engaged in packing books in a carton. Although the material supply and the packed books are on about the same level, a long transport loaded operation which includes a change direction is necessary because the sides and flaps of the carton offer an obstruction. A material improvement could be effected by arranging a set-up as shown by the sketch, Fig. 29.

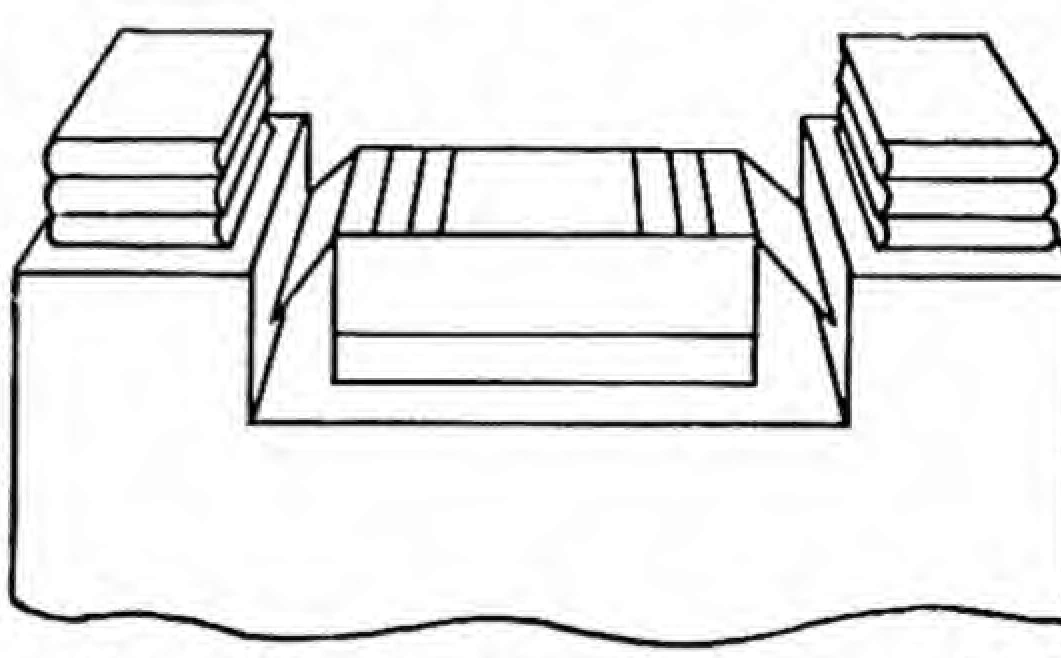


FIG. 29.—Improved set-up which shortens transport loaded and partially eliminates change direction.

Grasp is the basic division employed to take hold of an object and bring it under the control of the transporting device. This is usually a simple finger motion on small work, as when the thumb and forefinger are used to pick up a small screw, but it

may include a number of movements if the nature of the grasp is complicated. The number of times an object is grasped during the operation cycle should be reduced to a minimum, as well as the number of motions employed in grasping. Figure 30 shows the hand grasping the handle of a paper trimmer. This is shown

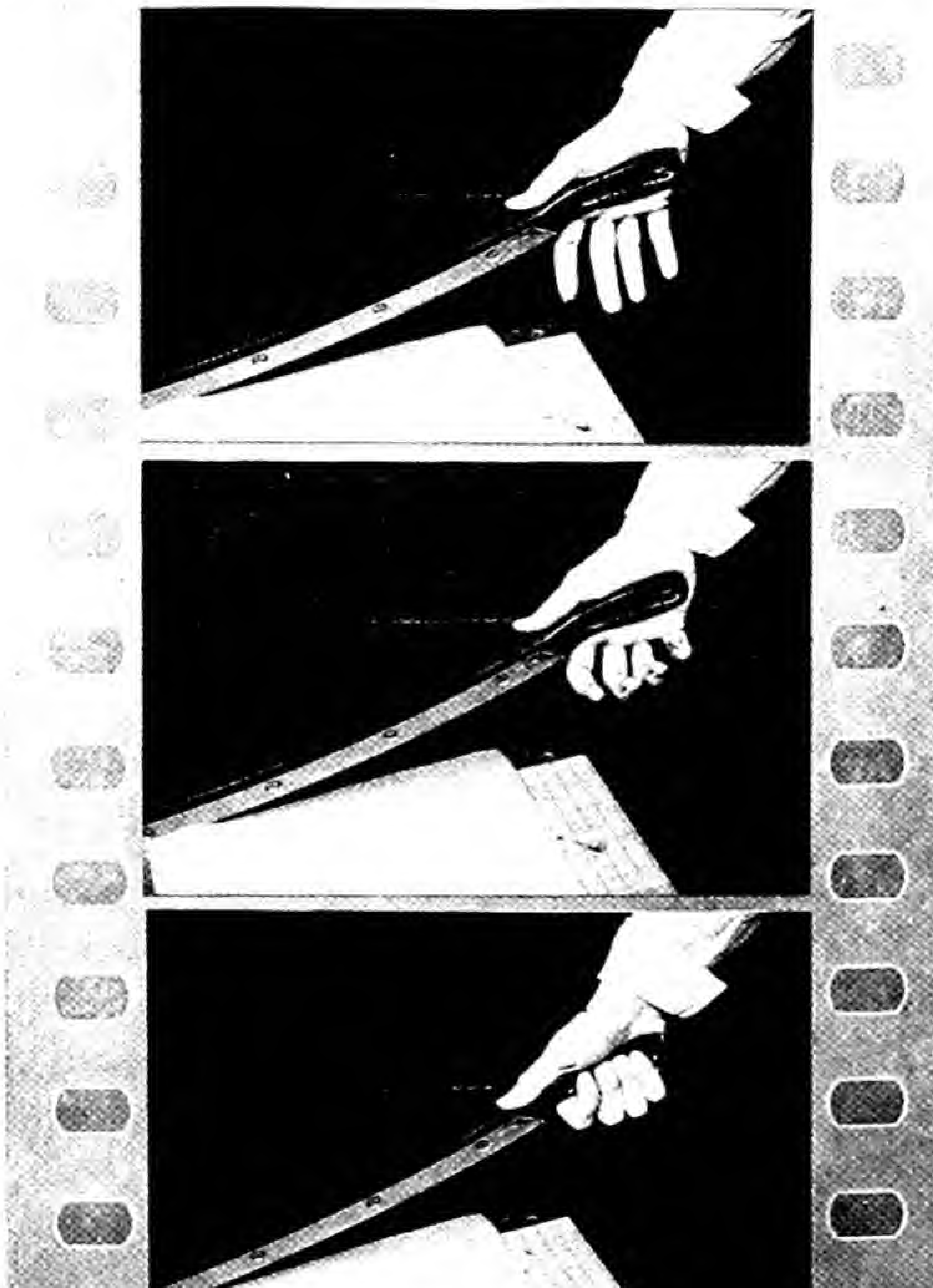


Fig. 30.—Grasp.

in a series of three pictures for the sake of clearness. Actually, grasp is performed so quickly that it usually lasts only one frame in a motion picture taken at the normal speed of sixteen frames per second.

Hold is the retaining control of an object after it has been grasped. The hand is an inefficient holding device and should

be replaced by a vise, a jig, or a fixture, so that the hand may be free to do more useful work. Hold should not be confused with use. A part may be held against a buffing wheel with the hands in order to polish it, but this is a use operation, for it is an objective operation. The hold operation accomplishes nothing but the maintenance of control of the piece. It is usually performed with one hand while the other performs several basic operations, one of which is use, as when one hand holds a small bushing while the other picks up a file, removes the burr, and lays the file aside.

Fig. 31.—Hold (left hand).

Figure 31 illustrates the left hand performing the hold operation, while the right hand tightens a nut with a wrench.

Release load is the basic operation that begins with the first movement away of any part of the grasping members and ends when all members have left the part and control has been completely relinquished. Figure 32 shows the hand just after it has performed the release division. The fingers have completely left the part which is falling away from the hand. Release is usually an extremely quick motion of about 0.00001 hour duration but may be longer if the grasping movements were complex.

Pre-position prepares either the transporting device or the object transported for the next basic division, which is usually

position. It does not often take place as an independent motion, but is usually done while some other motion is being made. For instance, in the transport loaded series, Fig. 27, it may be observed that the wrist and hand are pre-positioning while the arm is performing the transport loaded motion. At the first position, the hand is shown just after it has picked up the part from the table. The white edge of the part is somewhat out of position for assembling. As the right hand moves towards the

FIG. 32.—Release load (right hand).

left, the wrist turns the part, thus pre-positioning it. On large work, pre-position may be a separate motion. The pre-position basic operation should be carefully distinguished from the pre-positioning of tools and materials done when making the set-up. The latter pre-positioning is a function of general planning and involves a number of basic operations.

Position is the basic operation which places an object in a definite and predetermined relation with another object. It is often an accurate motion requiring mental as well as muscular control. It appears to the eye as a slight hesitation where little or no noticeable movement occurs. Position is a time-consuming

operation, and it should be eliminated or reduced in extent wherever possible. It can often be eliminated by using guides and stops which will position the piece automatically at the end of the transport loaded motion. Figure 33 gives an illustration of this. In the top picture, the hands are shown positioning a sheet of paper to a line on a paper trimmer. In the lower picture, a stop has been provided in the form of a wood block. When the stop is used, one hand alone can position the paper and the time

FIG. 33.—Position. Upper without stop; both hands required. Lower with stop; one hand required.

required has been reduced in the proportion of approximately 8 to 1.

Search is the basic operation employed to locate any object. If the work is properly planned, it should never be necessary. Search implies the necessity of finding. It can be eliminated by definite pre-positioning when making the set-up and establishing the motion sequence so that search is not necessary. When material of an irregular nature which must be picked up in a certain way is furnished to the operator jumbled about in a container, it is often necessary to perform a search operation to look for a part which is in the proper position for grasping. If the

work is highly repetitive, it may pay to deliver material lined up in a uniform manner in order to avoid both the search and the subsequent pre-positioning.

Select is the basic division of choosing among several items which have been found as a result of searching. In actual practice, even during the analyzing of a motion-picture film, it is almost impossible to tell where search stops and select begins. Both appear as hesitations during the motion sequence. If

FIG. 34.—Plan.

search can be eliminated, select is usually eliminated at the same time.

Plan is a delay or hesitation in order to decide upon the method to be followed. This basic division cannot be eliminated altogether, but the motion sequence should be arranged so that all planning is done at one point in the cycle. The major part of the planning is done during the set-up and may be done by several individuals. Figure 34 shows an operator studying her instruction sheet to determine how the job must be set up. This is a plan operation. When the work is begun, planning will occur more frequently during the first cycle or two than it will subse-

quently. Planning time is indeterminate and must be found by measurement. Plan seldom appears on the improved each-piece process chart, for the planning is usually done by the methods engineer, the foreman, the operator, and others before the chart is drawn.

Inspect is the comparing of an object with a definite standard, or the search for desirable and undesirable characteristics. The inspect basic division may be performed with the eyes, as in Fig.

Fig. 35.—Inspect.

35, or with the nose, fingers, or other sense organs. The operation of gaging is not an inspect basic division, but is a combination of basic divisions including transport loaded and assembly (part to gage or gage to part). The division, inspect, is usually a pause or hesitation while the sense organs note the characteristics of the object. The time required depends upon the number of characteristics noted, method of noting them, and the size of the object inspected.

Avoidable delay is a delay which occurs when the sequence of motions recognizes no delay as being necessary. It is usually

introduced by the operator and may consist of anything from plain idling to an inadvertant personal delay such as that caused by coughing. This last may be unavoidable in so far as the operator is concerned, but it is avoidable with respect to the operation and is classed as such. Figure 36 shows an engine-lathe operator interrupting his work to discuss a completed job with the inspector. This delay is avoidable as far as the operation sequence is concerned, although it may be necessary in order to clear up some questionable point with the inspector. Avoidable delays are timed as foreign operations and are considered

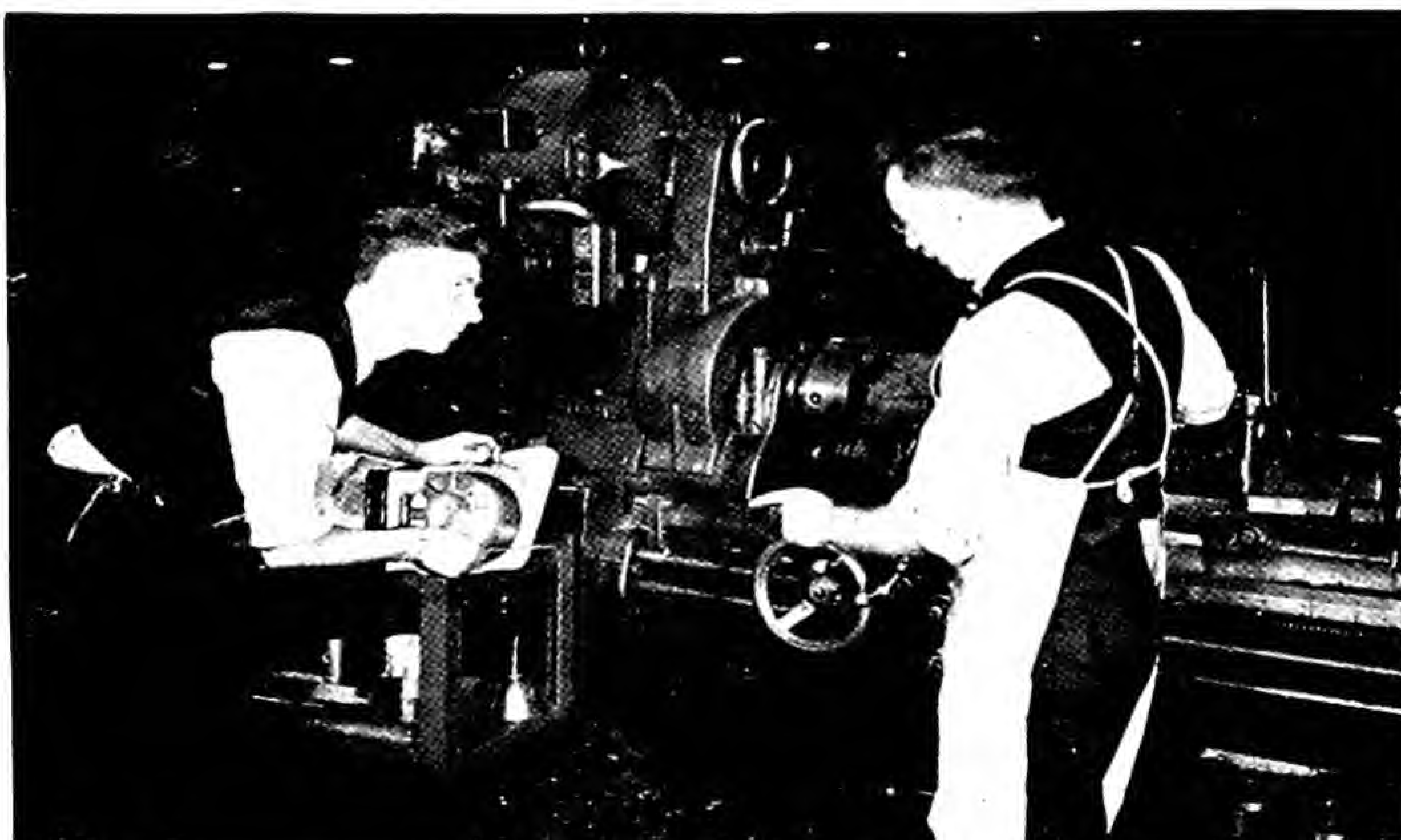


FIG. 36.—Avoidable delay.

under the subject of allowances. Avoidable delays are minimized by close and intelligent supervision and the application of incentive plans of wage payment.

Unavoidable delay in its most important sense is a cessation of work because of the arrangement of the motion sequence. The elimination of unavoidable delays is a function of the time-study man in that he should set up a motion sequence which will eliminate them. The unavoidable delay division is usually applied only to the hands. In the majority of cases, if both hands work usefully and continuously throughout the operation cycle, the motion sequence is considered to be properly planned. In other words, the activity of the hands is used as a basis of judging

efficient performance. It may be possible, however, to make still further improvements by transferring certain basic divisions to the feet or other bodily parts. If it is not, the fact that the feet or other bodily parts are idle does not mean that the operation is not properly laid out.

Figure 37 shows a common example of an unavoidable delay. The lathe operator is running up the carriage of his engine lathe with his left hand, a transport loaded operation. While the left

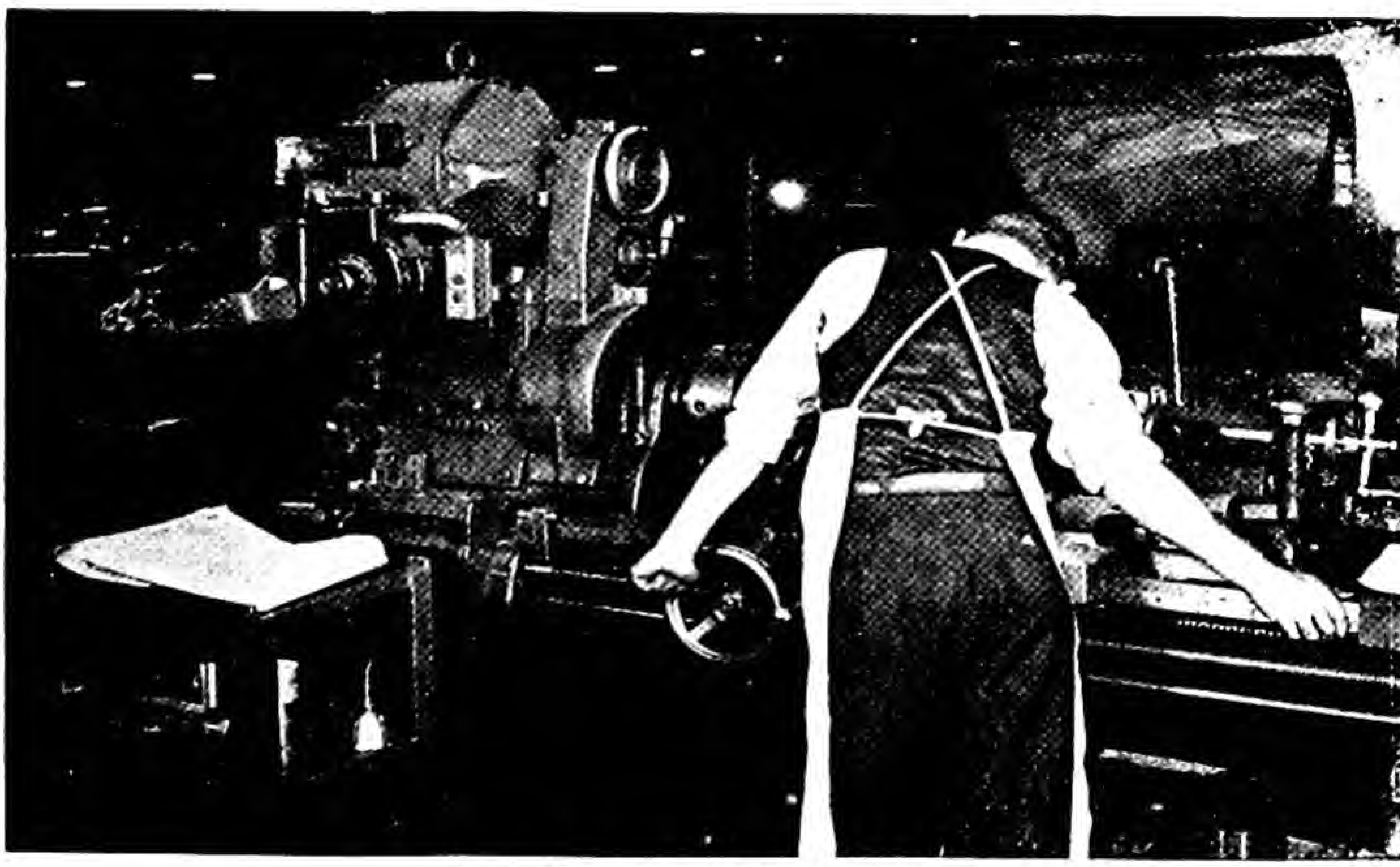


FIG. 37.—Unavoidable delay.

hand is doing this, there is nothing for the right hand to do. Thus, the right hand is experiencing an unavoidable delay.

The hand of the operator is not always idle and motionless during the unavoidable delay period. Often it will perform a useless motion, because it is less fatiguing to keep the hand in motion than it is to stop it completely and subsequently start it again. A blacksmith striking his hammer on his anvil while he turns a horseshoe over furnishes an excellent illustration of this point.

Rest to overcome fatigue is a delay allowed the worker for the purpose of recovering from exertion. On most operations, it is not allowed as a definite predetermined division, but is included in the general allowance. On work of a particularly exhausting nature, such as heavy drop-forging, it may be included in the

standard operation cycle. Where it is necessary, no attempt should be made to eliminate it. If the causes for exhaustion can not be removed, rest is necessary.

Balancing delay is a delay caused by the fact that it is not always possible to arrange the cycle so that each hand or other bodily part performs motions which require exactly the same length of time. If during the course of a cycle which is otherwise balanced, the left side must perform a shoulder, arm, wrist, and finger motion while the right side performs only a finger motion, there will be a balancing delay required for the right side. Or assume, for example, that an operator must grasp a casting with both hands preparatory to picking it up and that the left side is smooth except for a few shallow depressions as illustrated by the sketch, Fig. 38. Both hands perform the grasp division at the same time, but the right hand will be able to grasp more quickly than the left hand which must position its fingers carefully in the depressions to secure what few grasping advantages the casting presents. The right hand can complete its motion in the normal time and then remain idle while the left hand completes its motion, or the right hand can work more slowly than it ordinarily would. The latter is the more common occurrence, but in either case, the right hand experiences a balancing delay. Care should be taken to distinguish between balancing delay and unavoidable delay. Balancing delays occur when two bodily parts must perform an operation simultaneously, and one part is delayed by the slowness of the other. Unavoidable delays occur when one hand works and the other is idle, because the operation sequence is such that it cannot work. The difference is not difficult to recognize in practice.

FIG. 38.—Balancing delay. Right hand experiences balancing delay because it can grasp more quickly than left owing to nature of part.

Use is the basic operation that performs the process which is the purpose of the operation other than assembly. It is time which is usually out of control of the operator but not necessarily so. A drilling operation where power feed is used is out of control of the operator. The time for drilling a hole on a hand-operated drill press can be controlled by the operator within limits. Use

on machining operations often constitutes a large proportion of the cycle. When power feed is employed, the time consumed by

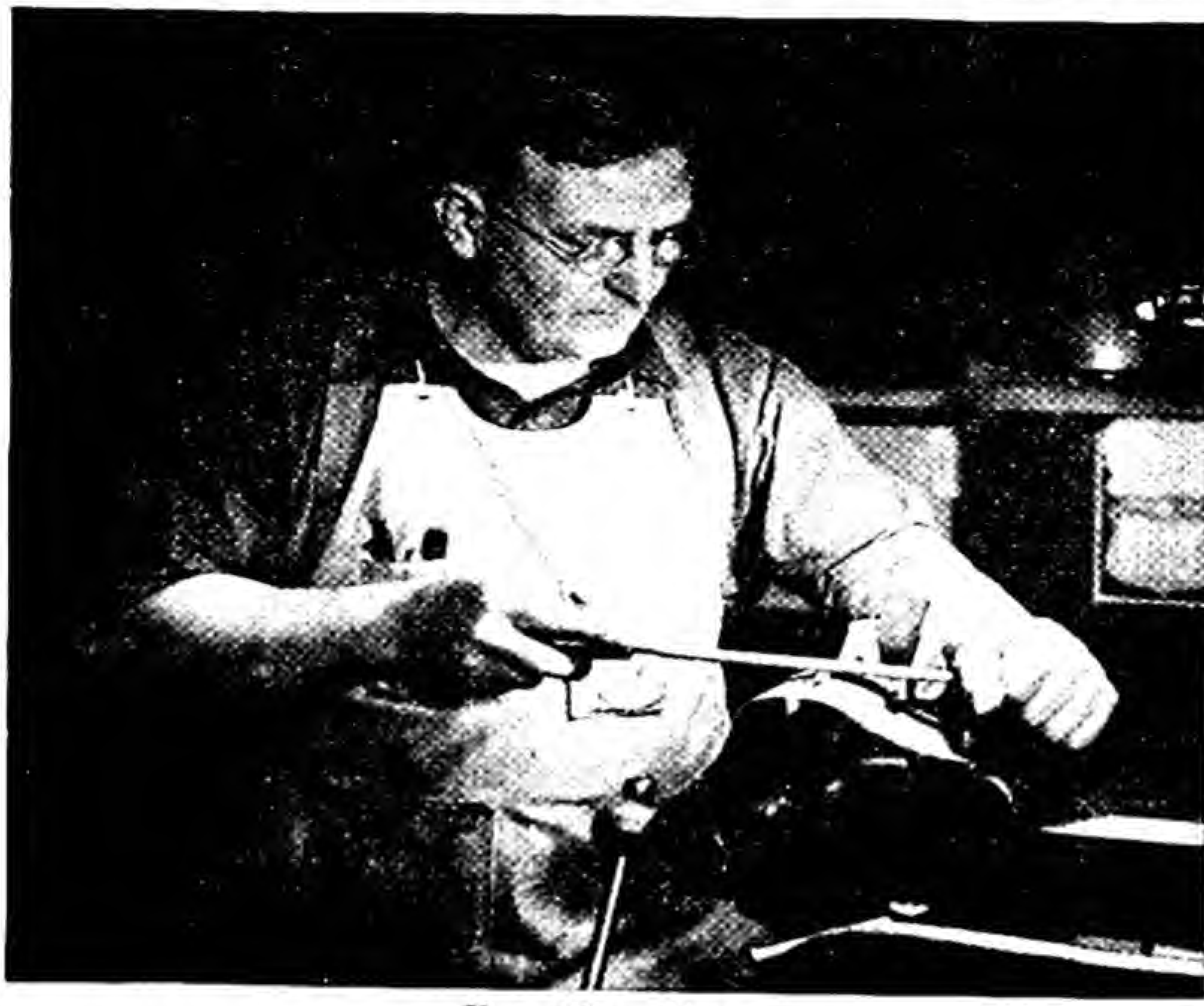


FIG. 39.—Use.

FIG. 40.—Assemble.

use may be utilized for resting, for preparing the next part for the machine, for performing a subsequent operation on the part just finished, for running a second machine, or it may be reduced

through improved mechanical equipment. The exact manner will depend upon the nature of the job and the length of the use division. Use is controllable within wide limits by the operator on hand operations, such as the filing operation illustrated by Fig. 39, and on hand-feed machining operations. The time for the use division may be shortened in much work of this nature by improving methods and equipment and by raising the performance level of the operator through instructions and incentives.

Assemble is the basic operation employed in bringing two or more parts into exact and predetermined relation with one another, as when assembling an end bracket to an electric motor as illustrated by Fig. 40. It is usually a group of motions rather than a single motion and as such can often be analyzed further profitably. Disassemble is the reverse of assemble, but there seems to be no particular advantage in distinguishing it from assemble by giving it a separate name and symbol.

Practical Value of Basic Division of Accomplishment Concept.—The basic division of accomplishment concept is of the greatest value in analyzing operations, for it enables one to detect inefficiencies whether he is familiar with the work or not. The basic operations of change direction, hold, pre-position, position, search, select, and the delays are all recognized as being inefficient, and if they can be eliminated from the cycle, the operation can usually be performed more quickly and with less fatigue.

The first step in the motion study of any job is to list the basic operations performed by each hand on an operator process chart. This may be done by observation or by the study of a motion picture of the operation. Figure 41 shows a simple operator process chart made from observation. The basic operations performed by the left hand are shown on the left-hand side of the chart, and those performed by the right hand are shown on the right-hand side. The basic operations are described in words and are classified by means of the basic operation symbols. Time is represented by the vertical distance between the small circles marking the beginning and the ending of each basic operation. When a chart of this type is prepared from observation, no attempt is made to depict time exactly. The relative time, however, for each operation based upon the observer's knowledge of motion time may be indicated as shown. When a film analysis is made, a more detailed type of operator process chart is usually drawn up, but it is constructed on the same principles.

In either case, when the chart is completed, the ineffective basic operations are distinguished from the effective operations, usually by marking with red pencil or distinguishing cross-sectioning on the chart. The starting point for methods improvement is thus provided.

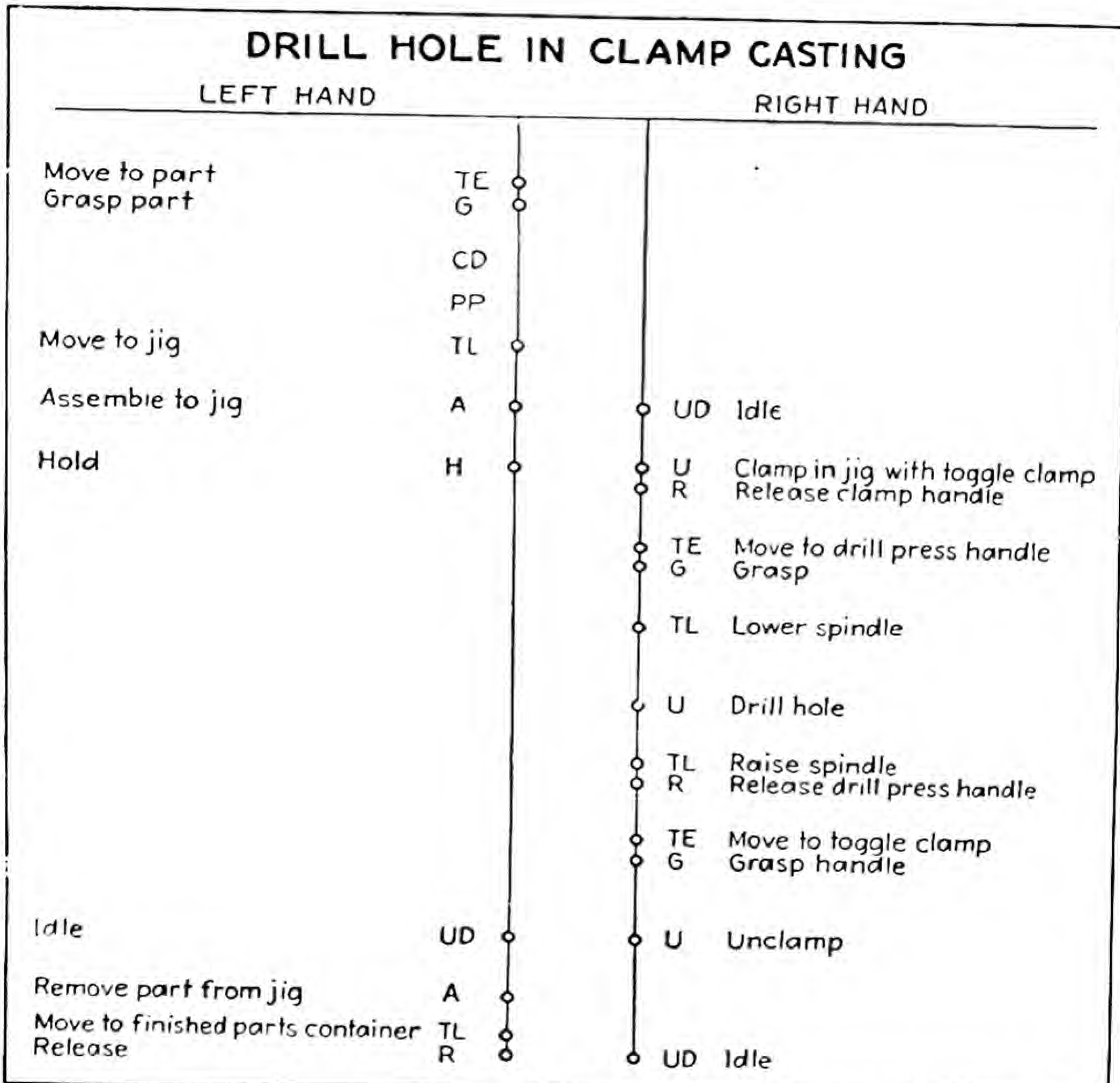


FIG. 41.—Simple operator process chart made from direct observation of operation.

In general, it may be said that the basic divisions of search, select, and hold should be eliminated altogether. Position should be eliminated or reduced where possible by stops and guides, as it is a time-consuming operation. Pre-position should seldom appear in the motion sequence as a separate operation, since the motion sequence may usually be set up so that pre-position can

be combined with a transport loaded. Plan should probably not appear at all on an operation of sufficient repetitiveness to justify the drawing up of an operator process chart. All unavoidable delays should be eliminated if possible, and if not possible, they should be reduced in extent and given to the least efficient hand to perform. The so-called effective basic operations should then receive further study in order to reduce them in number by rearrangement of work place, tools, and method and to shorten the remaining ones as much as possible.

The principles which are followed in setting up the new and improved method, after the inefficiencies have been eliminated, are known as the laws of motion economy, and they will be discussed in the next chapter.

CHAPTER VIII

LAWS OF MOTION ECONOMY AND THEIR COROLLARIES

A knowledge of the basic divisions of accomplishment and the ability to recognize them is of great assistance in making motion studies. This knowledge and ability permit the time-study man to reduce any job whatsoever to terms of basic operations. The next step is to analyze the present method used and the motions employed in order to devise a better method. The better method is in turn analyzed and improved, and the process is continued until no further improvement appears possible. The final method is then considered to be the best method, but this is generally qualified with the phrase "thus far devised" in recognition of the fact that it is usually possible, although not always practical, to bring about still further improvements by still more intensive study.

Principles of Motion Economy.—The trained time-study man does not go about his analysis of methods and motions haphazardly, but is governed and guided by certain principles of motion economy. These principles were originally stated in the form of 17 laws of motion economy. Experience in explaining these laws to time-study men and practical shop foremen has demonstrated that a restatement of these laws together with some amplification and clarification serves the useful purpose of making the meaning of the laws somewhat clearer. Therefore, this revision has been made, but those familiar with the original 17 laws will see that the most important of them have merely been restated in an attempt to anticipate and answer the questions which are likely to arise in the minds of those unfamiliar with the principles of motion economy.

The list has been rearranged to include what, because of their fundamental nature, may properly be called the five Laws of Motion Economy. In addition, eight corollaries are stated which amplify and elaborate upon the five laws. Corollaries, of course, are propositions which follow so obviously from others that they require little or no demonstration.

LAWS OF MOTION ECONOMY

1. When both hands begin and complete their motions simultaneously and are not idle except during rest periods, maximum performance is approached.

2. When motions of the arms are made simultaneously in opposite directions over symmetrical paths, rhythm and automaticity develop most naturally.

3. The motion sequence which employs the fewest basic divisions of accomplishment is the best for performing a given task.

4. When motions are confined to the lowest practical classifications, maximum performance and minimum fatigue are approached.

5. When conditions are the same, the time required to perform all basic divisions of accomplishment is constant for any given degree of skill and effort.

COROLLARIES TO LAWS OF MOTION ECONOMY

1. Hesitation, or the temporary and often minute cessation from motion, should be analyzed, studied, and its cause accounted for and, if possible, eliminated. When various parts of the body do not begin or complete their motions simultaneously, the resulting balancing delay should be recognized and recorded as being necessary.

2. The shortest time taken for each motion during the course of the study made on an expert operator should be considered the desired standard; all variations of time from this standard should be analyzed for each motion and the causes determined and recorded.

3. The best sequence of motions for any one class of work is useful for suggesting the best sequence for other kinds of work.

4. Where delay occurs, consideration should be given to the advisability of providing additional work which will permit utilizing the time of delay, if study indicates that the delay is unnecessary for overcoming fatigue.

5. All material and tools should be located within, or as near as possible to, the normal grasp area.

6. Tools and materials should be located so as to permit the following of the proper sequence of motions. The part required at the beginning of the cycle should be next to the point of release of the finished piece of the preceding cycle.

7. Tools and materials should be pre-positioned in order to eliminate the search and select basic operations.

8. Hands should be relieved of all work that can be done with the feet or other parts of the body, provided there is other work which the hands can do at the same time.

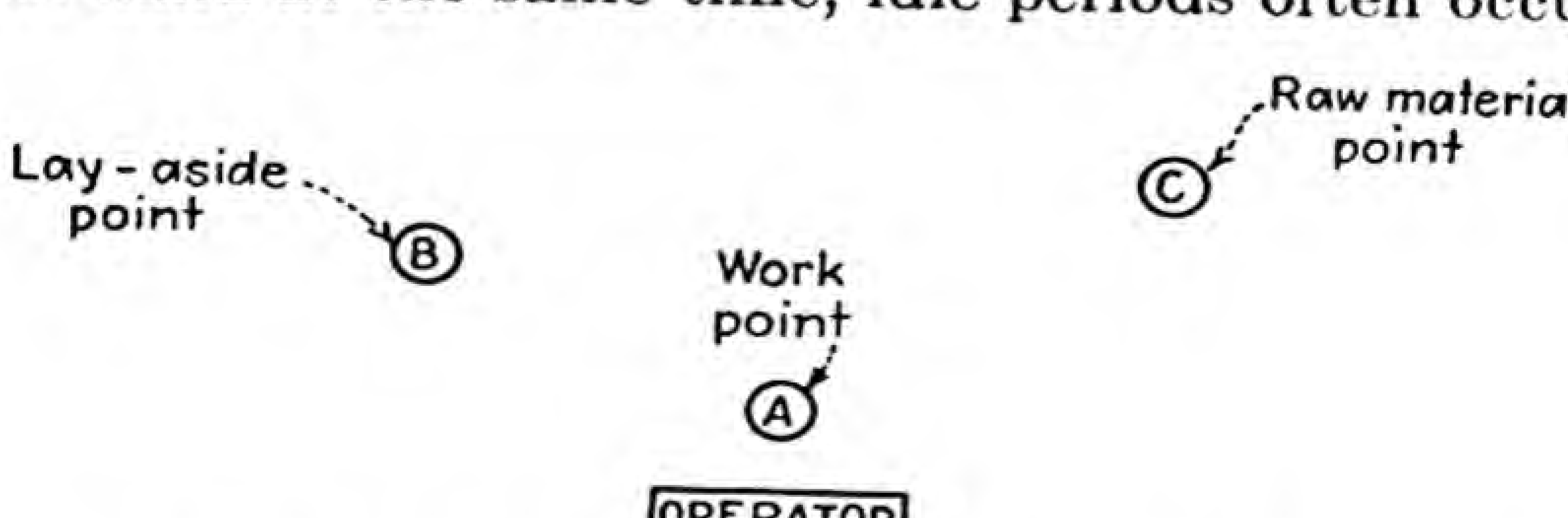
EXPLANATION OF LAWS OF MOTION ECONOMY AND THEIR COROLLARIES

LAW 1

When both hands begin and complete their motions simultaneously and are not idle except during rest periods, maximum performance is approached.

When both hands are working, it is desirable that they begin and complete their motions at the same time. In this way, a working rhythm is developed which carries the worker along toward maximum performance. If only one hand is working and the other is idle, only a part of the maximum possible efficiency is obtained. When one hand is working, the idle hand is not relaxed, and it does not rest. In fact, it is usually fatiguing to hold one hand motionless while the other is working. Workers, realizing this instinctively, will introduce balancing and otherwise useless motions to escape this type of fatigue. To recover from fatigue, all work should be stopped, and a rest period should be introduced. The operator can then relax completely and will become rested more quickly. "Rest to overcome fatigue" is the only permissible idle time, although "unavoidable delay" and "balancing delay" idlenesses can not always be altogether eliminated. The latter two, however, are never useful for overcoming fatigue.

On classes of work where it is not possible to do the same thing with each hand at the same time, idle periods often occur as the



operator works first with one hand and then with the other. Part of this idleness can be eliminated by overlapping motions.

Assume, for example, that an operator is working at the set-up shown by the sketch above and assume that, due to the nature of the mechanical equipment involved, workpoint *A*, lay-aside point *B*, and the point where raw material is obtained, *C*, must be in the relative positions shown. Assume further that the part worked upon, although bulky, can be handled with one hand. One way of laying aside the completed part and of obtaining the next would be as follows:

LEFT HAND			RIGHT HAND
		G	Grasp part
		TL	Move to point B
		R	Release
		TE	Move to point C
Idle	UD	G	Grasp part

This is a complete violation of Law 1. A better method would be:

LEFT HAND			RIGHT HAND
Grasp part	G		
		UD	Idle
Move to point B	TL		
Release	R		
		TE	Move to point C
		G	Grasp

Here Law 1 is still violated, but by putting both hands to work and overlapping their motions, the work is accomplished in less time. If the work place could be rearranged so that the work could be done as follows, Law 1 would be approached closely and maximum accomplishment would result:

LEFT HAND			RIGHT HAND
Grasp part	G	UD	Idle
Move to point B	TL	TE	Move to point C
Release	R	G	Grasp

Occasionally, even where work is set up for two-handed operation, the operator is found to be violating Law 1 and to be overlapping motions. To the casual observer, the operator may appear to be working continuously with each hand. In reality, however, minor idlenesses occur constantly when working this way, and fatigue increases rapidly because of the necessity of con-

stantly shifting attention from one hand to the other. Usually, as fatigue becomes great, overlapping ceases, and the operator works first with one hand and then with the other. He probably feels that he is working as hard as, or harder than, when he works in conformance with Law 1, as indeed he is, but he is making the common mistake of confusing effort with accomplishment. The time-study man should explain the reasons why maximum performance cannot be attained under this way of working and encourage the operator to work in accordance with Law 1.

Law 2

When motions of the arms are made simultaneously in opposite directions over symmetrical paths, rhythm and automaticity develop most naturally.

The principle of two-handed operation is expressed by the second law of motion economy, and its practical application leads to workplace layouts such as that shown by Fig. 42. Motions of the arms should be made simultaneously if Law 1 is not to be violated. They should be made in opposite directions from the axis of the body, for when this is done, one arm balances the other, and no body movement is necessary. If the arms are moved in the same direction, either to the right or to the left of the body, the whole trunk has to be shifted to balance the weight of the arms. This brings a number of body muscles into play and, on repetitive work, increases fatigue materially. If the arms must be moved in the same direction, they should move away from and toward the body rather than to the right or to the left, as the body can more easily balance a motion of this kind.

Motions should be made over symmetrical paths, or paths of the same shape, because most human beings are so constructed physiologically that one side of the body wants to work in unison with the other doing similar things. If the work place is laid out so that the right hand must follow a triangular path while the left hand is following a circular path, the operator will have difficulty in working in accordance with Law 1. There will be a tendency for both hands to move either along the triangular path or the circular path. To overcome this, the operator is likely to find himself working first with one hand and then the other. This tendency toward symmetrical movements of the two sides of the body has an important bearing on safety. If unsym-

metrical paths must be followed in moving near machinery, care should be taken to see that the tendency to change over into symmetrical paths will not carry the hand into a danger zone.

When motions are symmetrical, and in opposite or easily balanced directions, rhythm and automaticity develop naturally. Rhythm is most important and is attained by coordinating and synchronizing motions with respect to time rather than distance. When an operator works rhythmically, he works without con-

FIG. 42.—Workplace layout for two-handed operation.

scious planning or thinking, and hesitation and lost time are eliminated.

On large work, it is not always possible to arrange the motion sequence so that both hands work all of the time. In lining up motion sequences on work of this nature, however, the desirability of two-handed performance should be kept in mind, and it should be arranged for wherever possible. For example, large steam turbines are designed to suit each customer's operating conditions and are usually made in quantities of one. It would obviously be impracticable to draw operator process

charts showing every move each operator should make, for the turbine would be shipped before the charts could be completed. Each turbine spindle and cylinder, however, takes several hundred blades. The installation of these blades is in the nature of a repetitive operation, and it will be profitable to spend considerable time perfecting an efficient installation procedure.

Law 3

The motion sequence which employs the fewest basic divisions of accomplishment is the best for performing a given task.

Performing a basic operation consumes a certain amount of time. Therefore, every basic operation made should be analyzed with the idea of eliminating it or combining it with another. When, as a result, the work is performed with fewer basic operations, it will be performed in a shorter time. Furthermore, as the number of operations decreases, the fatigue per piece will decrease. There may be a few isolated cases where several short motions will consume a shorter time than a lesser number of longer motions, but this is rare enough to be considered the exception. Usually, the path of the lesser number of motions can be rearranged so that the time for performing them is reduced below the time required for the greater number of shorter motions.

Law 4

When motions are confined to the lowest practical classifications, maximum performance and minimum fatigue are approached.

All physical motions are divided into five classifications according to the bodily parts involved in making them. They are as follows, arranged with the most economical and least fatiguing first:

1. Finger motions.
2. Finger and wrist motions.
3. Finger, wrist, and forearm motions.
4. Finger, wrist, forearm, and upper-arm motions.
5. Finger, wrist, forearm, upper-arm, and body motions.

The fifth class requires a change of posture, while the first four do not. Motions of the first class are performed most quickly and with the least expenditure of energy, while motions of the fifth class obviously require more time and effort to perform. For example, it is possible to pick up a small part from a table, using only finger and wrist movements, in a fraction of the time

required to turn around and extend the arm to pick up the identical part. Hence, it is always desirable in arranging the work place and in determining the best method for doing the work to have as many as possible of the motions in the lower classes.

If all necessary motions could be reduced to the first class, no further improvement could theoretically be made. In studying any job, the ultimate aim should be to reduce all motions to the lowest possible class. The foregoing should, of course, be interpreted with common sense. It might be possible by exerting a prodigious effort to lift a heavy object an inch or so with a finger movement, but the same object could be lifted the same distance in less time and with far less fatigue by a finger, wrist, and forearm movement. In actual practice, there is no difficulty in recognizing the lowest *practical* classification.

In most cases, the attempt should be made to eliminate all fifth-class motions and to reduce as many fourth-class motions to third-class motions as possible. A more detailed discussion of the characteristics of the various classes of motions follows in the next chapter.

Law 5

When conditions are the same, the time required to perform all basic divisions of accomplishment is constant for any given degree of skill and effort.

The word "conditions" is used to cover all factors which can possibly affect the time required to perform a basic operation. It embraces not only such factors as light, heat, ventilation, and so on, but also such factors as nature of the part with respect to size, shape, and weight, distance moved, material, inspection and accuracy requirements, and the like. For example, among the conditions which affect the time for performing the operation of lifting a weight of 10 pounds a distance of 1 foot, a simple transport loaded operation, are temperature, location of the lift (near the floor, waist-high, overhead), material and condition of surface grasped (rough or slippery), bulk, and many others. But for a given set of conditions, if the skill and effort of two workers are the same, using skill in the limited sense discussed in Chap. XVI, they will take the same time to perform the operation. The concept, when grasped, is simple, but it forms the basis for all time allowances. If it were conceivable that an operator working at a given performance level would perform the same operation

under the same conditions in a different length of time on one occasion than on another, then it would be impossible to establish definite standards. On the contrary, however, by eliminating through standardization all or nearly all variations in conditions, it is possible to establish accurate performance standards. Any operator can equal the standard performance by meeting the skill and effort requirements upon which it was based, or can exceed it by increasing skill or effort, or both.

Corollary 1

Hesitation, or the temporary and often minute cessation from motion, should be analyzed, studied, and its cause accounted for and, if possible, eliminated.

Hesitation implies lost time, and since it is the purpose of motion study to eliminate lost time, steps should be taken to eliminate hesitation whenever it occurs. The first step in this elimination is to recognize the cause of the hesitation. The basic operations of position, search, select, and plan all appear as hesitations. In addition, very short unavoidable delays may seem to be minute hesitations. When the factor causing the hesitation is known, its elimination is often relatively simple. Position, as has already been pointed out, may be eliminated or greatly reduced by devising stops and guides. Search and select may be eliminated by proper pre-positioning of tools and materials at the time the workplace layout is made. Careful advance planning and proper operator training should eliminate the necessity for planning during the repetitive part of the job. Finally, unavoidable delays may be eliminated by rearrangement of the sequence of operations and by setting the job up so that it can be done in conformance with the first and second laws of motion economy. It is, of course, not feasible to do all of the things suggested on every job studied, but an earnest attempt should always be made to do so.

Corollary 2

The shortest time taken for each motion during the course of the study made on an expert operator should be considered the desired standard; all variations of time from this standard should be analyzed for each motion and the causes determined and recorded.

When studying several cycles of an operation, one will find that the elemental times vary. This is as true for the basic divisions of

accomplishment timed with the aid of the motion-picture camera as it is for the larger elements of the operation timed with a stop watch. It is reasonable to assume that if an element can be done within a certain time once, it can be done within that same time again, provided the conditions are the same. Using the shortest time taken by an expert operator as a standard, an attempt should be made to ensure that this standard will be attained on all cycles. An investigation of the elements taking more time will often reveal definite causes, the elimination of which will tend to make all elemental times approach the lowest as a limit. If the sequence of motions is such that rhythm and automaticity develop naturally in accordance with Law 2, motion paths will become standard and motion times will become equal. It must be borne in mind that the standards established by the expert operator are marks to be attained and that they must be leveled if they are to be used with any incentive system which uses the average performance as a base.

Corollary 3

The best sequence of motions for any one class of work is useful for suggesting the best sequence for other kinds of work.

Each study made should not be considered as an entirely new investigation. Operations are made up of various combinations of basic divisions of accomplishment. If the best combination has been found for one job, the possibility of applying it to another similar job should be considered. Where more than one time-study man is working on motion study in the same plant, arrangements should be made for the interchange of ideas through reports, process charts, motion pictures, and discussion groups.

Corollary 4

Where delay occurs, consideration should be given to the advisability of providing additional work which will permit utilizing the time of delay, if study indicates that the delay is unnecessary for overcoming fatigue.

Provision of additional work to utilize periods of delay is an important factor toward cost reduction. The length of the delay period will largely determine the use to which it is put. The most common application of this principle occurs when an operator is given one or more additional machines to run while his first machine is making a cut. Sometimes part of the operation per-

formed on one piece can be done during the idle period occurring on another piece. For example, on a certain shaft turned in an engine lathe, the operator was required to stencil a part number. His practice was to place the shaft in the lathe, take the cut—a power feed operation during which he was idle—and then stencil on the number while the shaft was still in the lathe centers. A rearrangement of the motion sequence was suggested, and thereafter he removed the shaft from the lathe without marking it, and applied the stencils while the cut was being taken on the next piece. This reduced the overall time of the operation by the time required for stenciling without appreciably increasing the fatigue of the operator.

Corollary 5

All material and tools should be located within or as near as possible to the normal grasp area.

The area in which the worker performs his operation should be kept at a minimum. Wherever possible, material and tools should be so arranged that the operator can perform the operations by moving hands and arms only. The height of the work area should be such that the operator is able to work either seated in a comfortable chair designed so as to secure a minimum of fatigue with a maximum of freedom of movement, or while standing. Thus, he will be able to vary his position from time to time and reduce his fatigue. Where the work is so large or so complicated that it is necessary for the operator to move about in performing it, the distance which it is necessary to move should be reduced as much as possible by the proper arrangement of the work place.

When the operation can be performed within a limited space, the following principles advanced by the Gilbreths should be kept in mind when laying out the working area. Assume that a worker is comfortably seated at or standing by his bench or table of proper height. His arms hang naturally from the shoulders. Placing his right hand on the near edge of the table approximately opposite his left side, point *A*, Fig. 43, he can sweep his right hand through the arc *AB* without any noticeable use of the shoulder muscles and with a normal expenditure of energy. The area included between this arc and the edge of the table represents the normal or most comfortable working area for the right hand. With the arm fully extended, the arc *CD* may be described which

represents the maximum reach of the right hand without change of posture. Likewise the normal *EF* and maximum *GH* working areas may be determined for the left hand.

Obviously, work requiring both hands can be most comfortably done in the overlapping area *AJE*. Second choice will be area *CKG*, with preference for the portions *CLJA* and *EJMG*, where at least one hand may work in its normal area. Right-handed workers may prefer *CLJA*, giving a greater effort to the more dexterous hand, and left-handed workers may prefer *EJMG*. With the nearer areas occupied, the more distant parts of the normal areas may be used for work requiring only one hand, or for

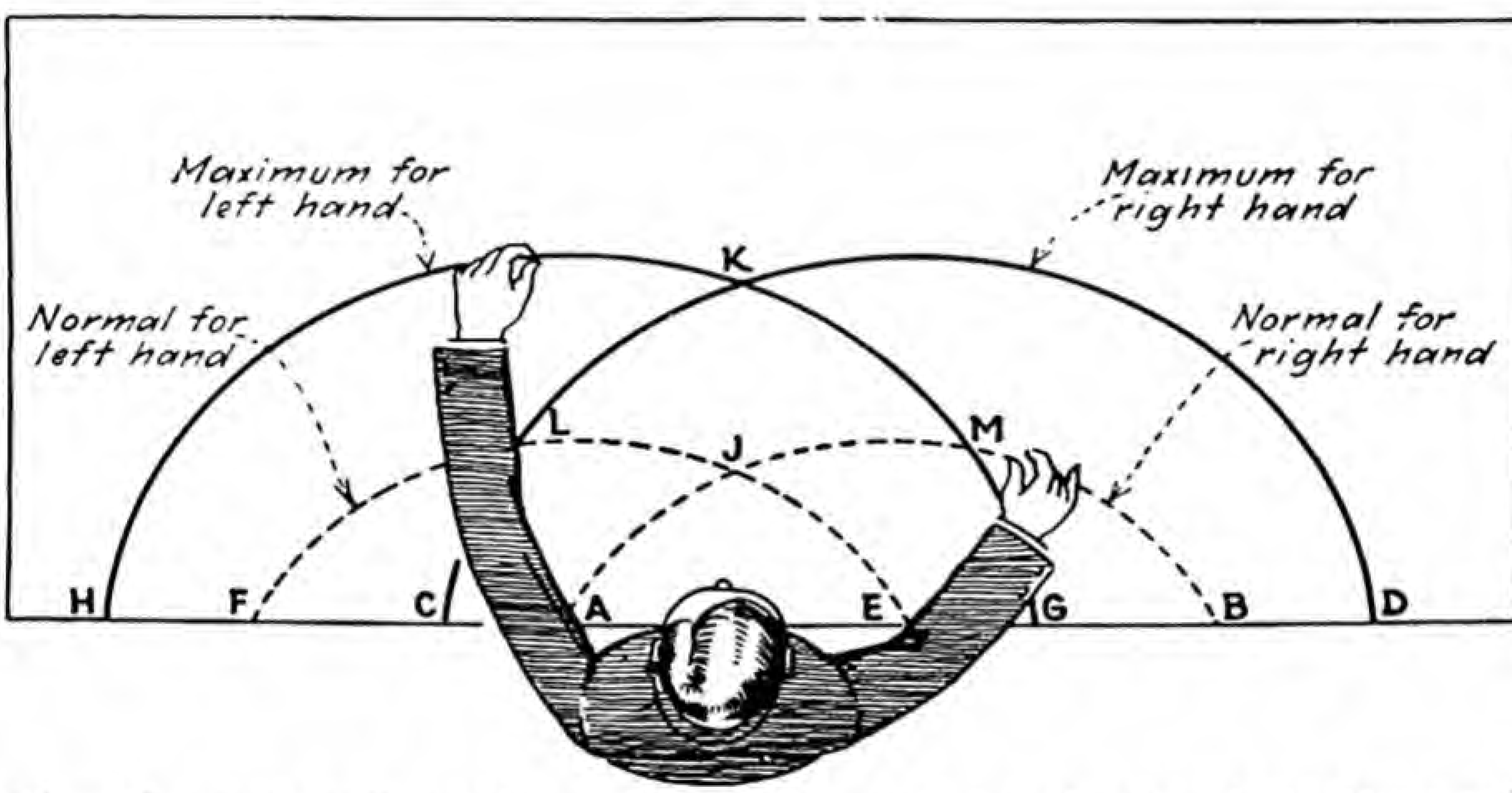


FIG. 43.—Normal and maximum working areas for the hands in the horizontal plane.

tools and material that may be picked up and used or replaced with one hand.

The principles of the normal and the maximum working areas are valuable for guiding the layout of work places in making set-ups. The idea of the circular work place was evolved from this concept. These set-ups are a great improvement over the older set-ups where material and tools were placed either haphazardly or in straight lines which caused at least part of the material to be located in inconvenient positions. They are not, however, the most efficient arrangements which can be devised in many cases.

Referring to Fig. 43, the normal working area for the left hand is *FLE*. It should not be assumed, however, that one point within this area is as easy to reach as another provided the dis-

tance moved by the hand is the same, for this is not the case. The points which lie along the arc *FLE* can be reached with a motion of the third class. To reach all other points, an additional shoulder motion is required, or a motion of the fourth class must be made. It requires more time to make a fourth-class motion than it does to make a third-class motion of the same length. Thus, when it is possible to confine all motions to the third class, material should

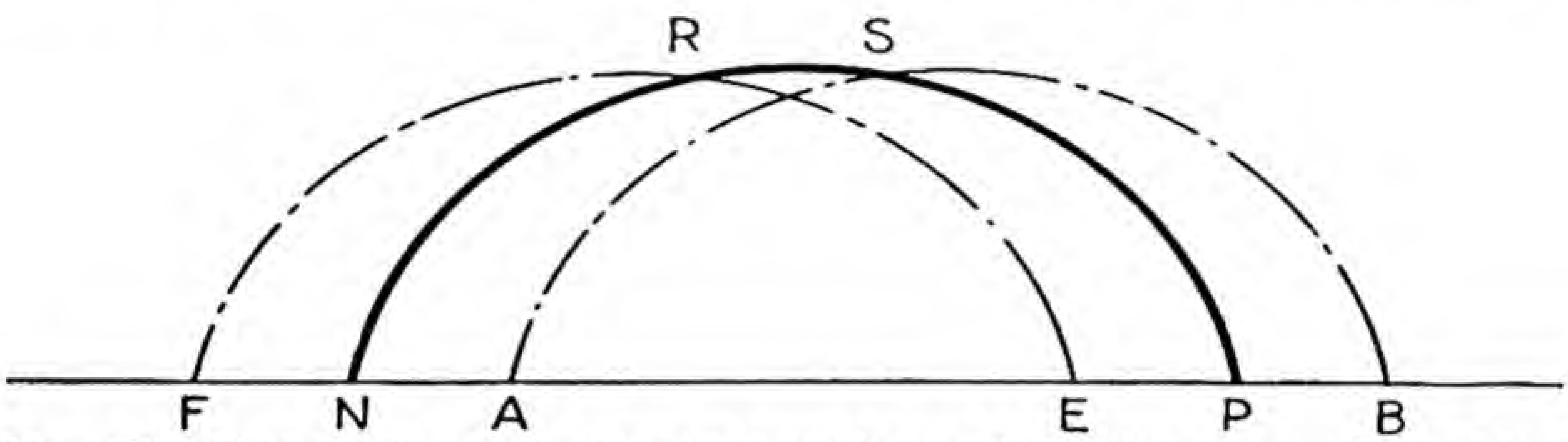


FIG. 44.—Circular work place coincides with arcs bounding normal working area at only two points.

be placed only along the paths which the hands normally follow, or along the arcs *FLE* and *AMB*. The only point where the hands can work together without involving the use of shoulder motions to change the position of the arms is the point *J*. In reality, this is not a point but a small area, which is determined by the wrist and finger motions which can be used without moving the arms.

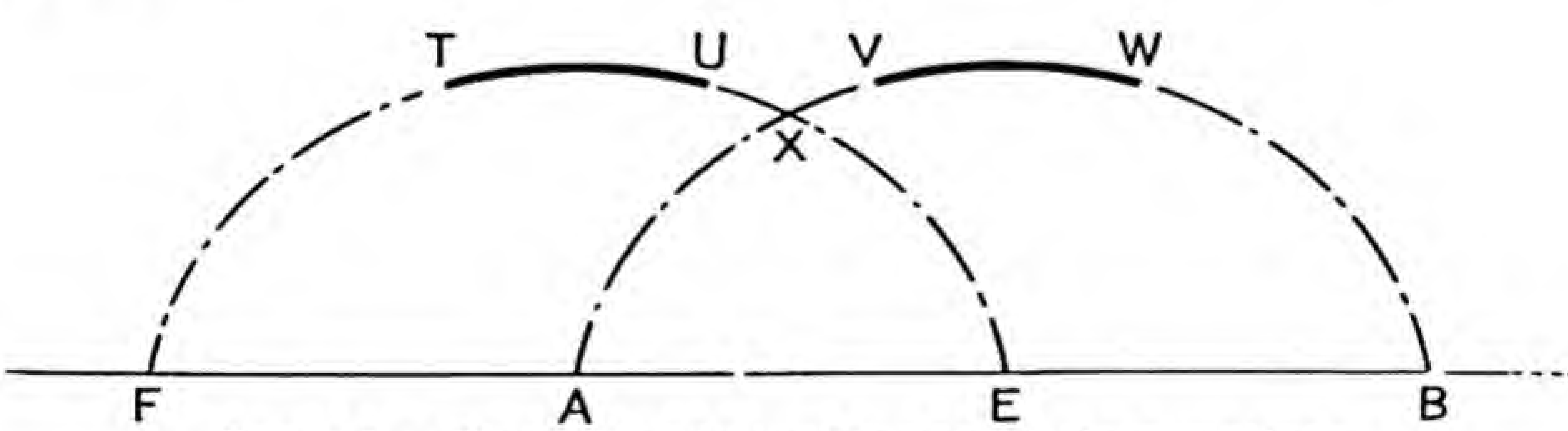


FIG. 45.—Workplace layout for third-class motions.

The arc of a circular work place, as conventionally laid out, will coincide with the normal arcs of the two hands at only two points. This is shown schematically by Fig. 44. When *FE* and *AB* are the arcs described by the left and right hands respectively when making third-class motions and when *NP* is the arc of a circular workplace set-up, the hands can reach only points *R* and *S* on the arc *NP* when pure third-class motions are used. Hence, a better arrangement would be that shown by Fig. 45. The arcs *TU* and

VW represent the space which should be occupied by materials, and *X* is the point where the work should be done.

This set-up is useful for small assemblies where only a few different parts are involved. It is not generally profitable to place material too near the points *F* and *B*, for the length of the movement required to reach these points becomes relatively great. A short fourth-class movement could be made in less time, which suggests putting another row of material containers in front or in back of *TU* and *VW* if much material must be positioned.

To reach a point anywhere within the area *HKGELF* of Fig. 43, a fourth-class movement must be made. In positioning material within this area, the chief concern should be to keep the length of the movements at a minimum. If possible, the area near *HF* should not be used. Besides involving maximum travel, it requires a rather awkward and fatiguing wrist motion to reach material located in bins in this area. The same, of course, applies to the areas on the right.

When a good set-up has been worked out, it should be used every time the job is done. If a job is not worked upon continuously, the set-up is likely to be torn down when one order is finished, and when the next order comes through, the set-up may not be made as originally worked out by the time-study man. The time-study man, of course, will have records showing the proper set-up, but arrangements should be made so that it will not be necessary to consult him continuously about set-ups, once he has worked them out. This can best be accomplished by arranging the material containers on a light frame made of strap iron. When an order is finished, the set-up is picked up bodily and is stored until wanted again. Information regarding the position of the containers on the frame and the material they hold may be painted on the bottom of the containers, so that they will always be placed in the same position.

Where many such set-ups are used, several designs of racks and containers can be adopted as standard. They can then be manufactured cheaply in quantities. When a new job comes to the shop, the time-study man can determine the type of rack and containers which should be used and can make the entire set-up in an hour or less. When racks and containers are available, it will be possible to make efficient set-ups for comparatively small quantity work.

In the vertical plane, the arc described by the fingers when a third-class movement is made is the arc AB of Fig. 46, while the arc CD is the maximum arc employing a fourth-class movement. These arcs determine the efficient placement of materials in the vertical plane.

When positioning tools which are suspended above the work area, care should be taken to locate them within the sphere which would be generated if the arc CD were to be rotated about the body of the operator as an axis. If no other equipment or material interferes, the tools should be located on the surface of the sphere which would be generated by similarly rotating the arc AB. In any case, they should be located so that they can be grasped without the necessity of employing body movements.

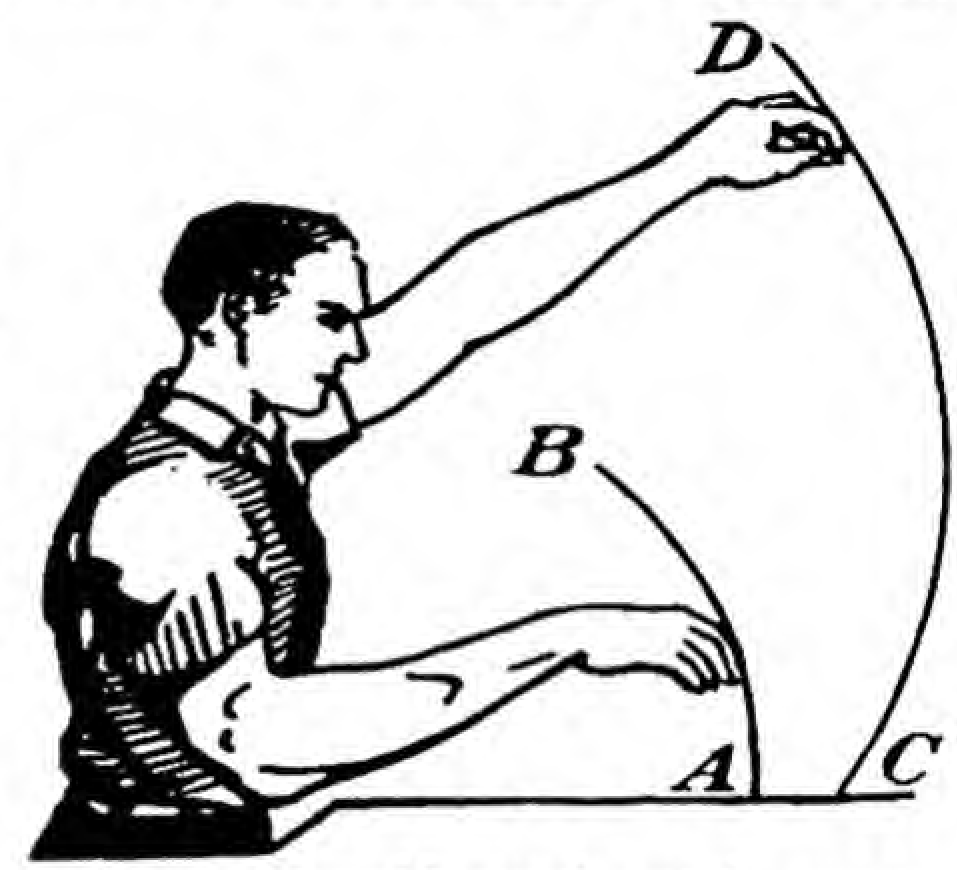


FIG. 46.—Normal and maximum working areas for the hands in the vertical plane.

The principles of efficient work areas should be applied to all lines of work, for they are universal. It is customary to think of them in connection with bench operations, but they can and should be applied to the arrangement of tools and materials around machines or on work such as molding, forging, and the like.

COROLLARY 6

Tools and materials should be located so as to permit the following of the proper sequence of motions. The part required at the beginning of the cycle should be next to the point of release of the finished piece of the preceding cycle.

An operation may be performed within the normal working area and yet be performed very inefficiently because of improper arrangement of tools and material. In general, one operation of a sequence should end at the same point that the next begins. If tools and materials are not so arranged, the transport motions will be needlessly long.

COROLLARY 7

Tools and materials should be pre-positioned in order to eliminate the search and select basic operations.

Search and select, with a find division implied, are not considered as productive motions and should be eliminated. As a result of pre-positioning at the time the workplace layout is made, the operator knows exactly where each part is at all times and can grasp it without involving the preliminary motions of search and select.

Corollary 8

Hands should be relieved of all work that can be done with the feet or other parts of the body, provided there is other work which the hands can do at the same time.

Any time that an operation can be performed by parts of the body other than the hands, it should be done if there is other work which the hands can perform at the same time. In this way, the hands are relieved of performing certain motions and time is saved in accordance with Law 3. The foot-operated drill press is an illustration of this principle. The operator works the drill spindle by a foot pedal, leaving both hands free to place drilled parts aside and get other parts to be drilled.

Application of Laws of Motion Economy and Their Corollaries. The full meaning of the laws of motion economy and their corollaries is seldom fully grasped at the first reading. Because they are universally applicable, they are expressed in rather general terms, and it is sometimes difficult to see how they apply to a specific operation or class of work. Therefore, it is recommended that after a careful study of the laws and their corollaries, a serious attempt should be made to apply them to a definite operation. In this way, their full import may be more readily recognized.

Consider, for example, the simple operation of "pick up small part," and assume that this part is to be used on an assembly. Where a motion study has not been made, the part will in all probability be in an ordinary container placed more or less conveniently wherever there is room on the bench. The basic divisions of accomplishment used in picking up the part will consist of transport empty, search, select, grasp, and transport loaded. Now in accordance with Law 3, the number of basic operations should be reduced to a minimum to secure the greatest operating efficiency. In addition, Corollary 1 states that hesitations should be analyzed and studied and if possible be eliminated. Hence, search and select at once become suspect. Analysis shows that they are made necessary because the parts are not

always obtained at the same point. The parts are scattered about a tote pan 26 inches long by 12 inches wide, and the operator must make a choice of which part is to be picked up. It at once becomes apparent that, the nature of the parts permitting, they should be placed in a bin or a hopper to be delivered one at a time at a fixed point by a gravity-feed chute.

As the result of providing such a chute, two basic operations are eliminated. Law 4 states that the motions employed must be reduced to the lowest practical classifications, and this forms the basis for the positioning of the gravity-feed chute when making the workplace layout. In order to comply with Law 4, the delivery point for the part should be as near as practical to the point at which the part is to be used. The chute should be arranged so that the transport motions are performed over a short path with a wrist or a forearm and wrist motion. The point from which the transport empty starts to the chute should also be as close to the chute as possible in accordance with Corollary 6.

Having done this so that one hand picks up the part quickly and easily, the next thing is to balance the motions of the other hand so as to meet the requirements of Laws 1 and 2. This may be done by arranging the set-up so that the other hand picks up another part of similar size, or by providing duplicate equipment so that both hands perform the same motions at the same time throughout the assembly, or in several other ways depending upon the nature of the work. If it is impractical to balance the motions exactly, delays will occur which must be analyzed and reduced to a minimum.

When the operation is at length standardized, and the best possible motion sequence is arranged, Law 5 states that the time for doing it will be constant for given skill, effort, and conditions, and hence a time value can be established with the certainty that it will always be correct as long as the same method is followed.

All parts of the operation cycle must be analyzed in the same way that the "pick up small part" element was analyzed. Experience will enable one to recognize almost instinctively when motion-eliminating devices are practicable. Parts which can be handled in gravity-feed containers are usually adapted to drop delivery. This feature eliminates useless transportation and simplifies the motion of releasing the part. When parts are machined or assembled in a jig or a fixture, ejectors can sometimes be used advantageously to remove the finished parts. These

devices partly or completely remove the parts from the jig or the fixture and eliminate the motions which occur when the hand has to grasp the parts to remove them. Similar practical methods of applying the laws of motion economy will become apparent as experience is gained with this phase of methods improvement work.

CHAPTER IX

CHARACTERISTICS OF MOTIONS

The study of the characteristics of motions offers a valuable approach to methods study. Physical motions are repeated over and over again by industrial workers, and a knowledge of the general nature of motions and the time required to make them can be most helpful in suggesting methods improvements by replacing long, fatiguing motions with shorter, less fatiguing motions.

Perhaps one of the most difficult things for the untrained observer to realize is the importance of each individual motion. A finger motion, for example, appears to take "almost no time at all," and hence it does not seem to be important whether the motion is made or not. On non-repetitive work, to be sure, the elimination of a single motion is of little moment, but on repetitive work each motion made during the operation cycle is worthy of detailed study. In a shoe factory, for example, it was found that every finger motion cost, on the average, $16 per year per operator per shift.

Another point which may be overlooked if the characteristics of motions are not understood is the desirability of shortening motions. To the unaided eye, it may not seem to require any more time to make a 12-inch third-class motion than it does to make one 10 inches long. When motion times are measured, however, it is found that each inch of travel consumes a measurable amount of time. Hence, on repetitive work, the shortening of motions offers a worth-while means of bringing about improvement.

The desirability of making a detailed study of each and every motion employed to perform an operation will depend upon the nature and repetitiveness of the operation, but an understanding of motions and relative motion times will give basic information which can be applied whenever the occasion arises.

Classification of Motions.—The five major classifications into which all physical motions are commonly divided have already

been given under the comments on the fourth law of motion economy. This classification is useful for visualizing quickly the different kinds of motions the human body can make, but when a more detailed study of motions is made, it is seen that still finer subdivisions should be made. A body motion, for example, might be a slight swaying of the trunk about the hips as a pivot, or it might be a total displacement calling into play a number of muscle groups, as in bending over to reach something on or near the floor.

A more useful although by no means complete classification, based partly on the bodily members moved and partly upon the bodily members or joints about which the movement is made, may be given as follows:

1. Finger motions.
2. Finger and wrist motions.
3. Finger, wrist, and forearm motions.
   a. Elbow acts as a pivot.
   b. Elbow acts as a ball and socket joint.
   c. Torsional movement.
4. Finger, wrist, forearm, and upper-arm motions.
   a. Shoulder acts as a pivot.
   b. Torsional movement.
5. Finger, wrist, forearm, upper-arm, and body motions.
   a. Trunk motions—hip pivot.
   b. Trunk motions—ankle pivot.
   c. Leg motions.
      (1) Forward or backward.
      (2) Side.
   d. Knee motions.
   e. Ankle motions.
   f. Combination motions.

Characteristics of Motions.—It is necessary to study in some detail how each of the above motions is made in order to be able to recognize and classify motions quickly and correctly when making studies. Even when the motions are thoroughly understood, it is sometimes difficult to recognize them when they are made quickly. When motions of this kind are encountered, slow-motion pictures are a valuable aid to analysis.

The finger motion is a motion of the finger or fingers alone, the wrist, elbow, and upper arm being stationary. Figure 47 illustrates two typical cases of finger motions. In *A*, the thumb and forefinger are starting a nut on a long stud. In *B*, the forefinger alone is running it down.

Experimental observations show that there is considerable variation in the minimum time in which different individuals can make finger motions. An average typist can make them faster than an average laborer, because she is more practiced in using her fingers. A trained concert pianist would be superior to both. At the same time, certain untrained individuals who have exceptionally good muscular coordination can make finger motions even faster than trained typists. This is because there is a difference in natural ability possessed by individuals on even such simple operations as making a finger motion.

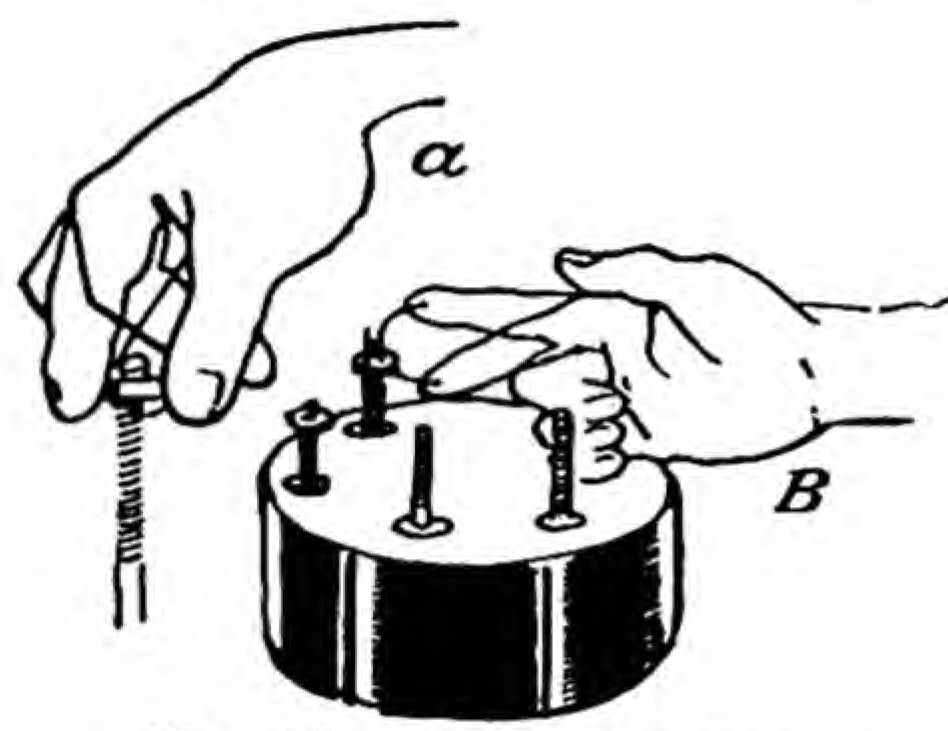


FIG. 47.—Finger motion.

The skill of any untrained individual can be improved by practice. The laborer, by constantly exercising his fingers, can train himself to make finger motions much more quickly than he could before practicing. There is a certain maximum performance, however, which the individual can attain and beyond which he cannot pass no matter how much he practices; this is fixed by his natural characteristics. Certain individuals seem to be born slower than others, and no amount of training will enable them to meet the speed of their more fortunately endowed fellows.

For a given individual, there is considerable difference in the time needed to make finger motions with the different fingers. Usually the index finger can move the fastest, because it is used most frequently and hence is the most practiced. The second and third fingers are slightly slower, the little finger much slower, and the thumb the slowest of all. This is only the average condition, however. Certain individuals in tests have been able to move the little finger or the thumb faster than the other fingers because of a natural aptitude for making motions of this sort. This variation in the ability of the individual to make finger motions suggests that for work requiring a number of finger motions, the operators should be tested to see whether they are able to move the fingers which must be most employed with at least normal speed. On certain counting operations, the thumb is used to leaf over the sheets being counted. Here the desirability of being able to make rapid thumb movements is clearly apparent.

Right-handed individuals can usually make finger motions with the right hand slightly quicker than with the left hand, although there are numerous exceptions. The finger motions of the right hand are also usually better controlled. There is not a great deal of difference between the finger motions of the two hands, however, and it is safe to say that the average operator can learn to use the fingers of either hand, with the possible exception of the thumb and the fourth finger, with equal dexterity. Most people can move all fingers together nearly as fast as the index finger alone and faster than any of the other fingers alone. Here again, however, there are exceptions.

The same general reasoning given for finger motions applies to all other classes of motions. Hence, only the general characteristics and the variations commonly encountered in individuals lacking special training will be discussed. Training will tend to raise the level of performance of any individual and will enable him to approach the performance of the expert as closely as his natural abilities permit.

The wrist motion is a motion of the hand and fingers about the wrist joint. The wrist motion is usually slightly slower than the finger motion, although there are the ever-present exceptions due to variations in natural ability. Wrist motions are usually rather fatiguing and are instinctively avoided by workers. Light riveting may be done with a pure wrist motion, as illustrated by Fig. 48, but it is more commonly done with a forearm motion. It is slightly quicker and much less fatiguing to make the wrist motion in the direction shown by Fig. 48 than in any other direction, although the difference in time is not great. If the wrist motion must be made against resistance, as when an object of appreciable weight is held in the hand while the wrist motion is made, the time required to make the motion is increased, and fatigue becomes much greater. The wrist motion is used largely to position the fingers to grasp or release something and is not much used for the transport motions, particularly transport

FIG. 48.—Wrist motion.

loaded. For the short distances which the wrist can travel, a forearm motion can be made as quickly and with much less fatigue.

The forearm motion where the elbow acts as a pivot is one of the most important motions on small work, and it should be employed wherever it can be used to advantage. The time required to make a forearm motion of this type depends upon a number of factors, among which are the distance moved, the resistance against which the movement is made, and the part of the arc AMB, Fig. 43, traced by the finger tips in making a third-class motion, in which the motion is made. Other factors such as right- and left-handedness, muscular control, and strength also enter in.

The greater the length of the forearm motion, the greater is the time required to make it. Forearm motions up to 2 inches in length, measured at the finger tips, can be made by some individuals even faster than finger motions. When made close to the body, point A of Fig. 43, they can be made most rapidly. At point M, they are made less rapidly, while at point B, if it can be reached at all, the motion is slow and most fatiguing. Resistance lengthens the motion time appreciably and increases fatigue.

Right-handed individuals make forearm motions more quickly and with better control with the right arm than with the left, although this can be nearly equalized by practice. Physical strength has greater influence on forearm motions than on first- or second-class motions, and in general a man will be able to make forearm motions faster than a woman.

FIG. 49.—Forearm motion; horizontal plane.

The forearm motion is generally an efficient motion to employ for the transport basic divisions of accomplishment, and workplace layouts which permit its use should be made whenever possible. Figure 49 illustrates a transport operation made with a third-class motion.

Forearm motions are often made in a plane other than the horizontal. Figure 50 shows a molder employing the motion in a vertical plane to peen his mold.

The forearm motion made with the elbow acting as a ball and socket joint is employed when circular motions must be made. The motion used to turn a hand wheel as illustrated by Fig. 51 is a motion of this type. The time required to make this motion for a given diameter of circle is only slightly longer than the time

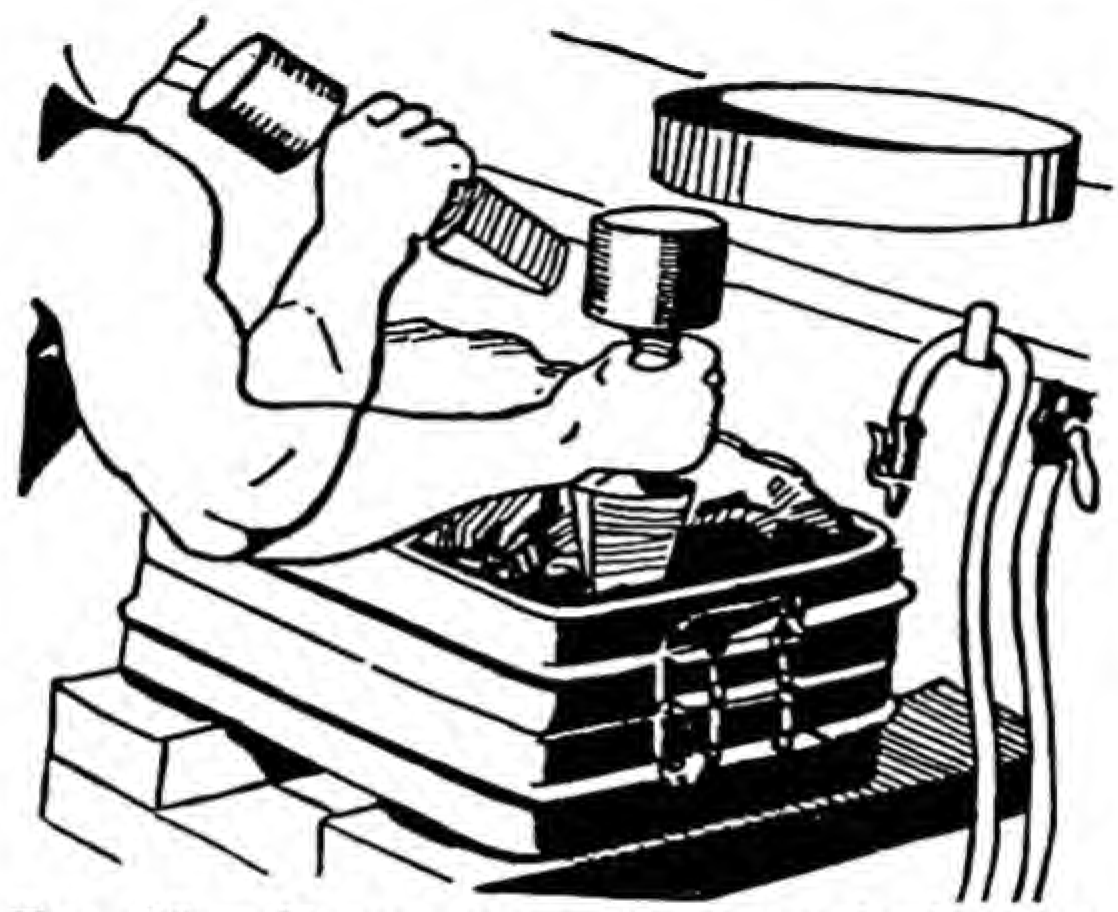


Fig. 50.—Forearm motion; vertical plane.

required to make an ordinary forearm motion forward and back along an arc equal in length to the diameter of the circle. The hand travels over a path longer by 57 per cent in the first case, but it travels at approximately constant speed, whereas in the second case the hand must be started, accelerated, decelerated, and stopped twice. This, of course, accounts for the difference in time per inch of travel.

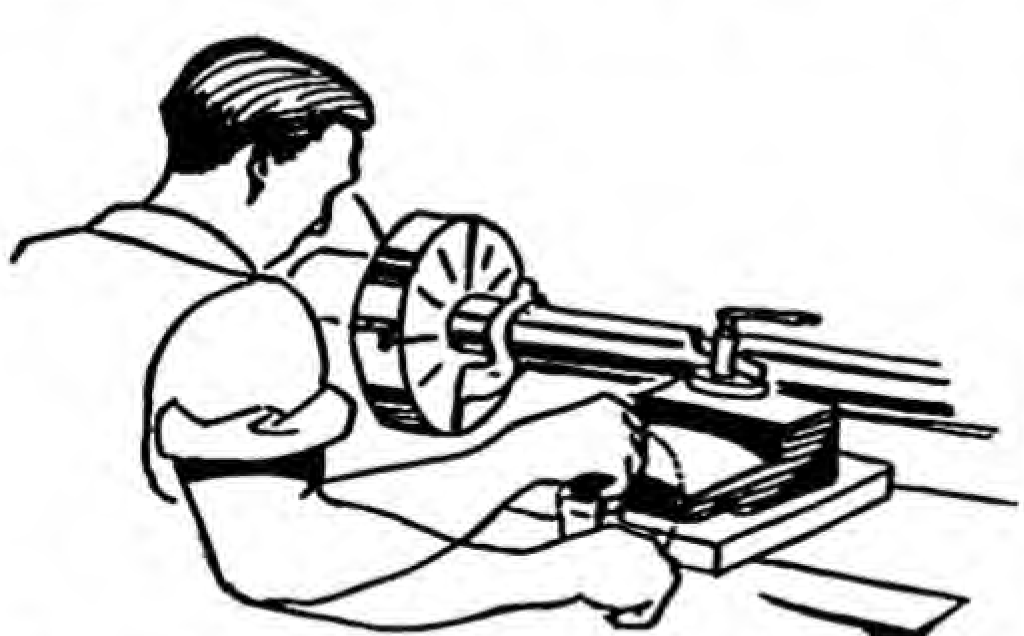


Fig. 51.—Forearm motion; elbow acting as ball and socket joint.

Another type of third-class motion is the torsional motion. This is a twisting motion pivoted at the elbow. A common application of this motion is illustrated by Fig. 52. The torsional motion is quite powerful, but is fatiguing if repeated frequently under heavy loads.

The fourth-class motion, or *shoulder motion,* is the one which is most used in industry, especially where work places have been laid out without a knowledge of the characteristics of motion. Short motions are so quickly made that it is difficult for anyone who has not made a study of the subject to realize that there is

any appreciable difference in the time required to make, say, a 6-inch forearm motion and a 6-inch shoulder motion. Experiments show, however, that the shoulder motion is definitely slower than the forearm motion of the same length.

The general characteristics discussed for third-class motions apply to fourth-class motions, with the exception that a fourth-

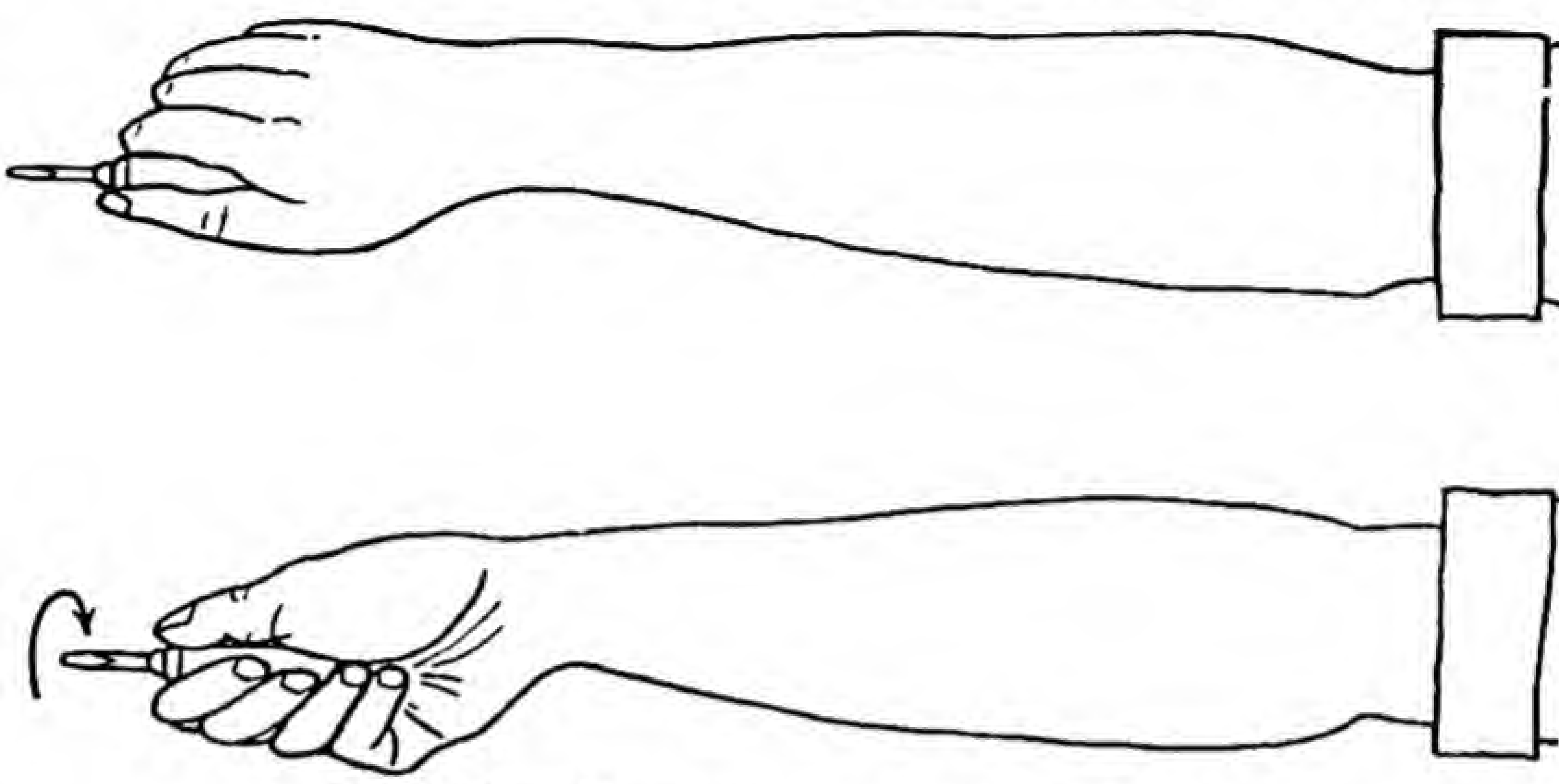


FIG. 52.—Forearm motion; torsional.

class motion may be made in one position as quickly as in another at all but the two extremities of the fourth-class motion path. Since these extremities are not likely to be used, this point is not important. Motions made with the arm fully or nearly fully

FIG. 53.—Shoulder motion.

extended are made nearly as quickly as when the hand is close to the body, but the fatigue is greater because of the additional energy needed to support the weight of the hand and arm. Figure 53 shows a painter using a shoulder motion in painting. The same motion is also employed for the transport basic operations on a job of this kind. The shoulder motion can be made in a

vertical plane or at any angle between the horizontal and the vertical.

There is also a fourth-class torsional motion. It is similar to the third-class torsional motion, but the pivot is about the shoul-

FIG. 54.—Body motion pivoted about hips.

der. It is more powerful, but slower and more fatiguing than the third-class torsional motion.

FIG. 55.—Body motion pivoted about ankles.

Movements of the *body* about the hips or ankles as a pivot are not as easy to recognize, classify, and measure as are the movements of the arm and legs. In general, a pivot about the hips results when the worker is seated or is standing with his hips

firmly pressed against the edge of his workbench, while a pivot about the ankles is most natural when the worker stands with his body unsupported.

Body movements about the hips commonly occur when a seated worker must reach for material which is located outside of the maximum area which can be reached with a fourth-class motion. Figure 54 illustrates a case of this kind. The body movement can often be eliminated by moving the material closer to the worker.

Body movements about the hips or ankles made while standing occur on such work, as planing, sanding, scraping, and filing. They are also employed in reaching for material or machine control levers located outside the maximum work area. Figure 55 shows a body movement with the pivot at the ankles as it is used when planing.

The time for making the body movements depends upon the resistance against which the movement is made, the length of the movement, and the strength and muscular coordination of the operator. Body movements to the side can be made slightly faster than body movements backward and forward, but the difference is very slight.

Fig. 56.—Leg motion; forward and back.

Several types of *leg motions* are encountered in industry. The most common is the backward and forward motion. This is frequently used in moving the foot to the treadle of foot-operated machines such as the punch press shown in Fig. 56. The motion is also used in walking, of course, but is subject to great variations in speed in this case. The time to make backward and forward leg movements is affected by the distance moved, the resistance against which the movement is made, and the physical strength and agility of the individual. There is no appreciable difference in time between motions with the right leg and motions with the left. This is to be expected, for since both legs are in constant use on the same sort of motions, *i.e.*, walking, running, and so on, they should be equally developed.

Side leg motions are used for moving sideways and for operating certain machines such as the vertical boring mill shown in Fig. 57. If the operator is properly braced, the time for making the side leg motion is approximately the same as for the backward and forward leg motion, and it is affected by the same variables. It is more difficult to balance a side leg motion with the body than the backward and forward leg motion, because it is less natural, and hence greater fatigue is induced in untrained individuals.

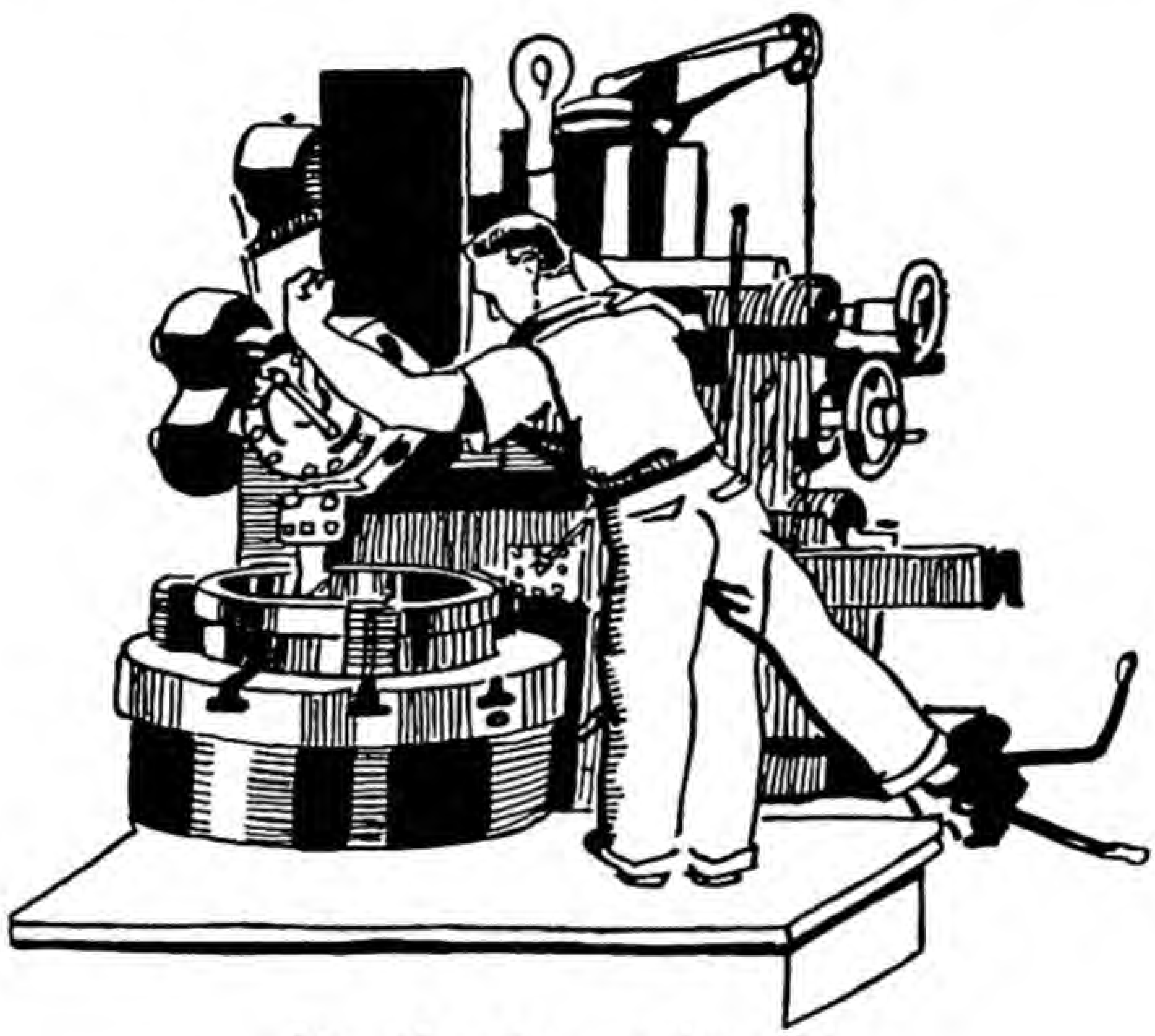


FIG. 57.—Leg motion; side.

The *knee motion* is a movement of the foot and lower leg about the knee as a pivot. This motion is used to move the foot toward a foot control or other object when the operator is seated. It is also used to operate certain special mechanisms such as that shown by Fig. 58. The machine is a riveter and the mechanism is such that a knee motion starts the machine and at the same time brings the hammer and anvil closer together as the movement is continued, thus permitting parts of varying thickness to be riveted without adjusting the machine. The time for knee motions depends upon the usual factors of resistance, length of travel, and physical ability. Again there is little difference between the right and the left sides.

The *ankle motion* is a movement of the foot about the ankle as a pivot. When made with the foot unsupported, it is a very

fatiguing motion and is difficult to control. When used to operate a treadle, as in Fig. 59—the most common application—the fatigue is greatly reduced, and the control is provided to a large extent by the mechanism being operated. The time for the motion made with the foot unsupported varies with the muscular coordination of the individual. When the foot is operating a treadle, the time is influenced and limited by the resistance of the mechanism.

Combination motions are often observed in industry, as, for example, when a furnace man in a foundry picks up a 100-pound ingot from the floor and throws it into the furnace door 12 inches

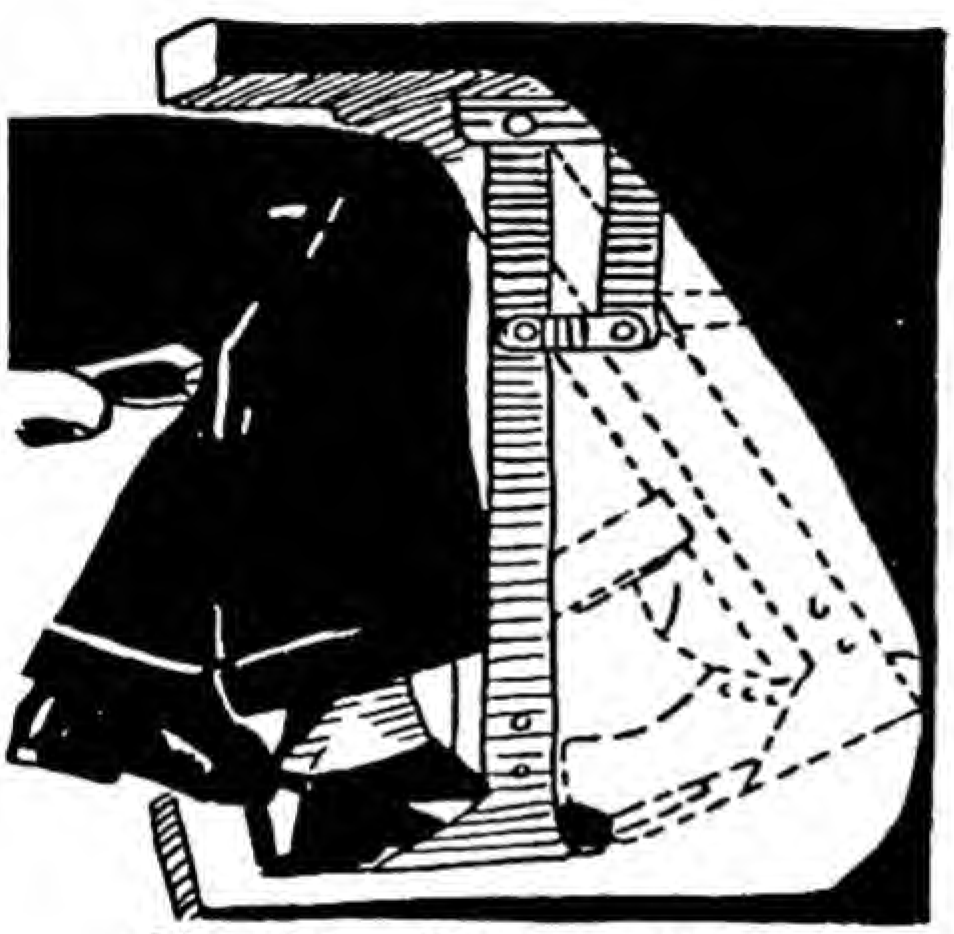


FIG. 58.—Knee motion.

FIG. 59.—Ankle motion.

above the level of his head. In a case of this kind, almost every joint and bodily member is brought into play, although from a basic division of accomplishment standpoint it is a simple transport loaded operation.

Combination motions are so many and so varied that they have not yet been definitely classified and studied. As a group, however, they are used on but a small percentage of industrial work. The vast majority of industrial operations are performed by using only the motions which have been discussed above. Usually when a combination motion is encountered, an attempt should be made to reduce it to a more simple motion by a rearrangement of the workplace layout.

Study of Motion Times.—The study of the time required to make the various classes of motions under varying conditions yields a great deal of information about the characteristics

of motions, much of which has practical application value in methods improvement work.

There has been a recognized need for basic time standards in industry, and several attempts have been made to establish a set of time data which will be universally applicable. A typical set of such data is shown by Fig. 60. Much progress has been made in this connection, but in order to evaluate the usefulness of such data, an understanding of the problems surrounding its compilation and application must be obtained. This discussion will, therefore, be confined to the development of this understanding rather than to the presentation of any specific standards.

TABLE OF PREDETERMINED MOTION-TIME STANDARDS

Motion class	Minimum time, seconds	Time per motion in seconds, uncontrolled motion—average effort
Finger motion	.....	0.108
Wrist motion	.....	0.120
Forearm—elbow pivot	0.100	$Y = 0.00324\ X + 0.093$
Forearm—elbow ball and socket (approx.)	0.248	$Y = 0.00214\ X + 0.203$
Shoulder	0.128	$Y = 0.00338\ X + 0.118$
Trunk motion—hip pivot	0.343	$Y = 0.150\ Z + 0.343$
Trunk motion—ankle pivot	0.215	$Y = 0.0903\ Z + 0.150$
Leg motion—forward or backward	0.160	$Y = 0.0468\ Z + 0.143$
Leg motion—side	0.195	$Y = 0.050\ Z + 0.195$
Knee motion	0.160	$Y = 0.0468\ Z + 0.143$
Ankle motion	.....	0.192
		X = distance moved in inches
		Y = time in seconds
		Z = distance moved in feet

FIG. 60.—Motion-time data.

The minimum time in which any given motion can be made offers a starting point for motion-time determination. The minimum time required by a given individual to make a motion can be learned by timing him while he makes the motion with maximum effort. Studying motions made with maximum effort offers several definite advantages. In the first place, the most consistent results will be obtained. It is difficult for an operator to exert consistently any effort other than his best. He may attempt to exert what he considers an average effort, but he will find that his conception varies from day to day and even from trial to trial. Furthermore, different operators will have different ideas about what constitutes their average effort so that data collected on several operators will vary greatly. The maximum

effort is more easily determined by all, and hence results will be more consistent.

In addition, certain factors show up when the excessive or maximum effort is used. The study of maximums quickly reveals individual differences in ability, differences between men and women, young and old operators, and so on. The difficulty in controlling certain motions becomes apparent when the motions are made at maximum speed. The relative fatigue induced by different motions also is quickly noticed. None of these factors shows up if lesser effort is used in studying the motions.

The length of time required to make a single motion of almost any type is so short that it cannot be timed accurately without special apparatus. If a motion is repeated a number of times, however, by counting the number of times the motion is made in a given period the time per motion can be computed. A period of 0.0030 hour, or approximately 11 seconds, has been found to be satisfactory for studies of motion times. Care must be taken to avoid errors in counting and timing, but, properly used, the suggested method will yield valuable motion-time data.

Plan and Control Factors.—Every motion is affected by two sets of factors which may be classed as direct and indirect. The direct factors are those which are directly related to the work being performed, such as the class and length of motion which must be employed, weight of the part, direction of motion, and so on. The indirect factors are those which affect the motion largely through the mind and muscles of the operator. There are two of these indirect factors, and they may be referred to as plan and control.

Plan is the mental work which accompanies the physical work. If an operator is inexperienced, the physical work is likely to be performed more quickly than the mental. His hands will get ahead of his mental processes, and there will be hesitations while the mind is catching up and deciding what to do next. As skill increases, the mind begins to work ahead of the hands. This is evidenced by a decreasing amount of hesitation and by the fact that the eyes of the operator will travel ahead of his hands instead of with or behind them. When superskill is reached, mental and physical processes alike become habitual. Motions blend into one another so smoothly that it is difficult to follow them, and all hesitation is eliminated.

When an operator first starts a job, he will have to do considerable planning. On the first piece, he will hesitate many times and will feel his way along. On the second piece, this hesitation will be somewhat less pronounced. As he produces more and more pieces, hesitations become less frequent, and, in shop parlance, he begins to get into the swing of the work. The overall each-piece time decreases progressively until a minimum is reached when the operator attains the highest degree of proficiency which his natural capabilities permit. This may be expressed graphically by the curve, Fig. 61, showing the ratio of overall time to minimum time for each successive part produced on a given job. Thus, piece number 1 takes the longest to pro-

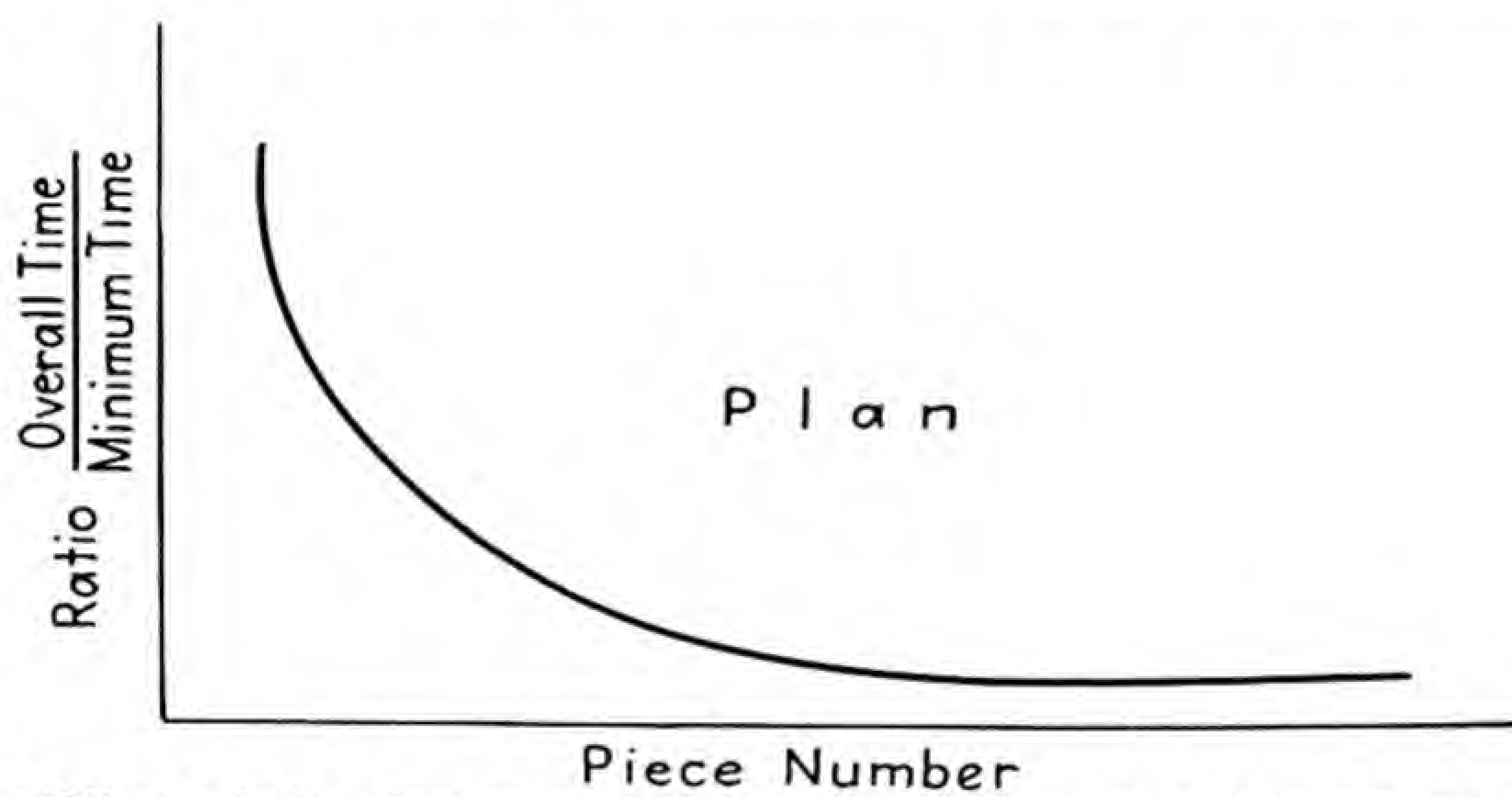


FIG. 61.—Effect of plan factor on ratio of overall time to minimum time as number of pieces produced increases.

duce, and piece 2 requires somewhat less time. Piece 50 is made in less time than piece 49, piece 74 in less time than piece 73, and so on until the minimum time is reached, and the ratio of overall time to minimum time becomes unity. The curve varies quantitatively in accordance with the complexity of the operation, the length of the operation cycle, and the ability of the operator, but qualitatively it is the same for any job.

The factor of control exerts a similar influence on the cycle time. When control must be exerted, motions will be made comparatively slowly on the first few pieces. If the work place is arranged so that the motions employed on each piece are the same, the operator will gradually develop muscular automaticity. Motions will speed up, and there will be less fumbling at the points where the motion must be brought under control. Thus, the control factor will gradually reduce, and plotted graphically,

as in Fig. 62, the ratio of overall time to minimum time will decrease as each successive part is produced in the same manner as for the plan factor, although the curve will decrease less sharply.

This concept of plan and control explains many points which have heretofore puzzled time-study men. It is apparent, for example, why operators are able, when they have worked upon several thousand parts, to gain greatly on a time allowance established by a time study taken after 50 parts were produced, even though the method followed remains the same. They have minimized the necessity for mental planning and have established habits of muscular automaticity which reduce conscious control greatly.

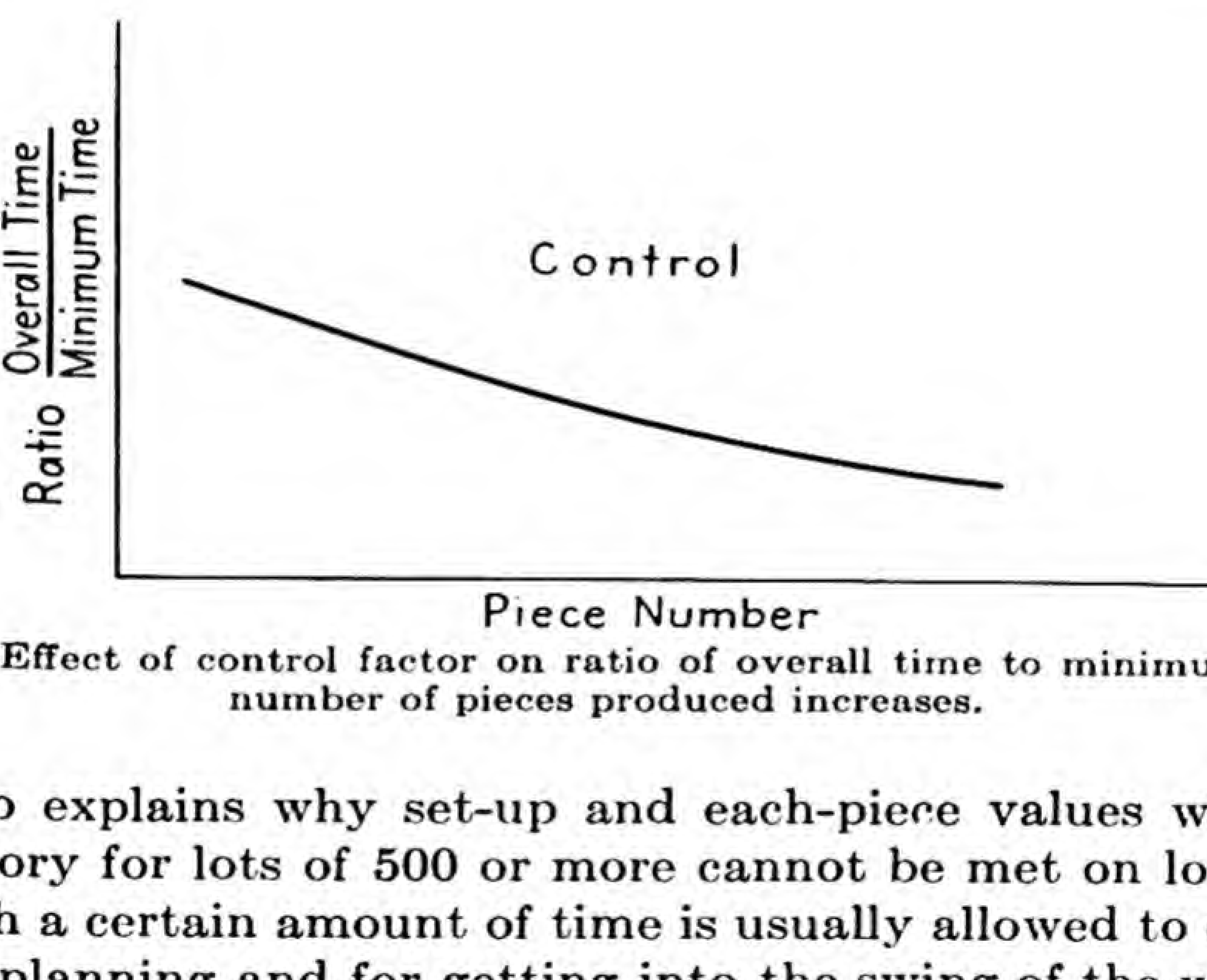


FIG. 62.—Effect of control factor on ratio of overall time to minimum time as number of pieces produced increases.

It also explains why set-up and each-piece values which are satisfactory for lots of 500 or more cannot be met on lots of 10. Although a certain amount of time is usually allowed to compensate for planning and for getting into the swing of the work, the amount allowed for this is constant, whereas the time consumed by these factors is a variable amount. Therefore, if a time value appears to be correct for lots of 500, the amount of time allowed for planning and control in the set-up is too low, but the each-piece allowance is too high, thus furnishing a compensating error. When only 10 pieces are worked upon, the operator is not able to make up on the each-piece time what he loses on the too small planning and control allowance, and hence, although he probably does not understand exactly why, he complains that the time value is wrong.

Theoretically, the correct way to handle set-up and each-piece allowance is to establish an each-piece value which is the minimum, and then vary the set-up as the number of pieces on the order varies. Referring to Fig. 63, *AG* represents the time for performing a given operation after the plan and control factors have been reduced to a minimum. The distance between the curve *AG* and the curve *BG* represents the time lost due to planning and control per piece at any given point of the job. If one piece is produced, the amount of time represented by *AB* should be added to the set-up. When pieces up to number *X* are produced, the time represented by the area *ABCD* should be added.

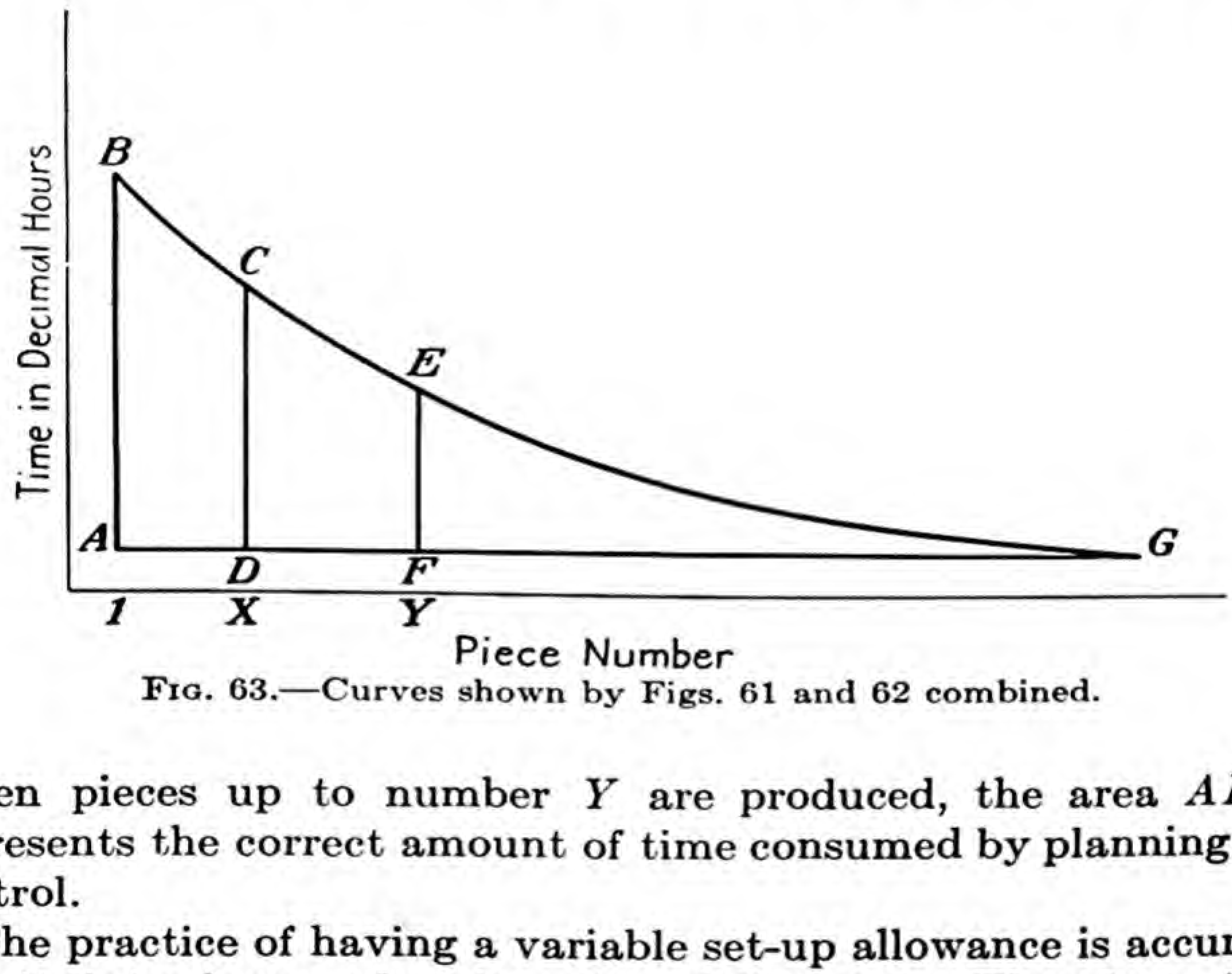


FIG. 63.—Curves shown by Figs. 61 and 62 combined.

When pieces up to number *Y* are produced, the area *ABEF* represents the correct amount of time consumed by planning and control.

The practice of having a variable set-up allowance is accurate, but it introduces administrative difficulties. Therefore, it is highly impractical to attempt to use it. An understanding of the nature of the plan and control factors, however, is useful for obtaining a better insight into some of the problems encountered in rate-setting work.

Basic Divisions of Accomplishment to Which Knowledge of Motion Times Can Be Applied.—A study of minimum motion times made in the manner suggested above will give data on the time required to make motions with the plan and control factors reduced to a minimum. Before they can be used, however, each

basic operation should be analyzed in detail to see how the data obtained will apply.

Transport empty, for example, is a purely physical motion. The suggested motion-time data are obtained from a study of transport empty motions. Hence, it may be said that the data may be used for determining the time required to perform transport empty operations uninfluenced by plan and control factors.

Transport loaded is similar, but the factor of the weight of the object transported enters in. Even if the weight is not great, the time for transport loaded is higher than the time for transport empty, and fatigue is greater if the operation is repeated frequently. As the weight of the object transported increases, the time for the transport loaded division increases materially.

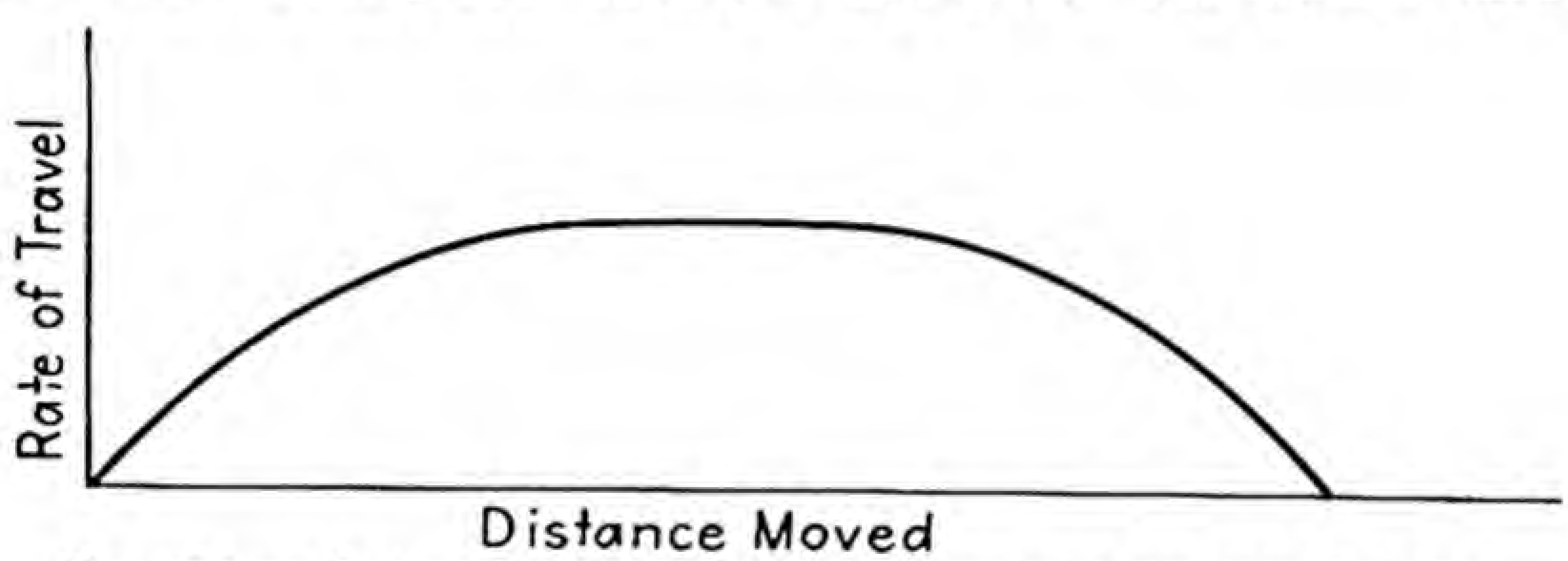


Fig. 64.—Rate of travel during transport empty motion.

Hence, both weight and distance moved must be taken into consideration when determining the time for the transport loaded operation.

When a *change direction* occurs during a transport motion, the time for that motion is somewhat increased. When a transport motion is made in a straight line, there is a start, an acceleration, a travel, a deceleration, and a stop. If rate of travel were to be plotted against distance moved, the curve would appear as in Fig. 64.

When a change of direction is involved, there is a slight deceleration as the direction of the motion is changed and a compensating acceleration as the movement is brought up to speed again in the new direction. These changes are slight and require special measuring apparatus to detect. If rate of travel is plotted against distance moved where there is a change direction, the curve appears as in Fig. 65.

The time for the *grasp* basic division depends upon the class of motion or motions employed for grasping and also upon the characteristics of the part grasped with regard to size, shape,

weight, and nature of surface. Most grasping is done with the fingers or with the fingers accompanied by a wrist motion. A light, easily handled part may be grasped as quickly as a finger motion can be made. Very small parts such as escutcheon pins or small screws require longer because the grasping motion must be more accurately controlled. Parts that are nearly as large as the span of the hand require longer to grasp, especially if they are heavy, because the grasping motion must be controlled and then muscular tension put on the fingers before the part can be lifted. Slippery, wet, hot, and cold parts require longer to grasp because of control requirements and perhaps certain other factors such as

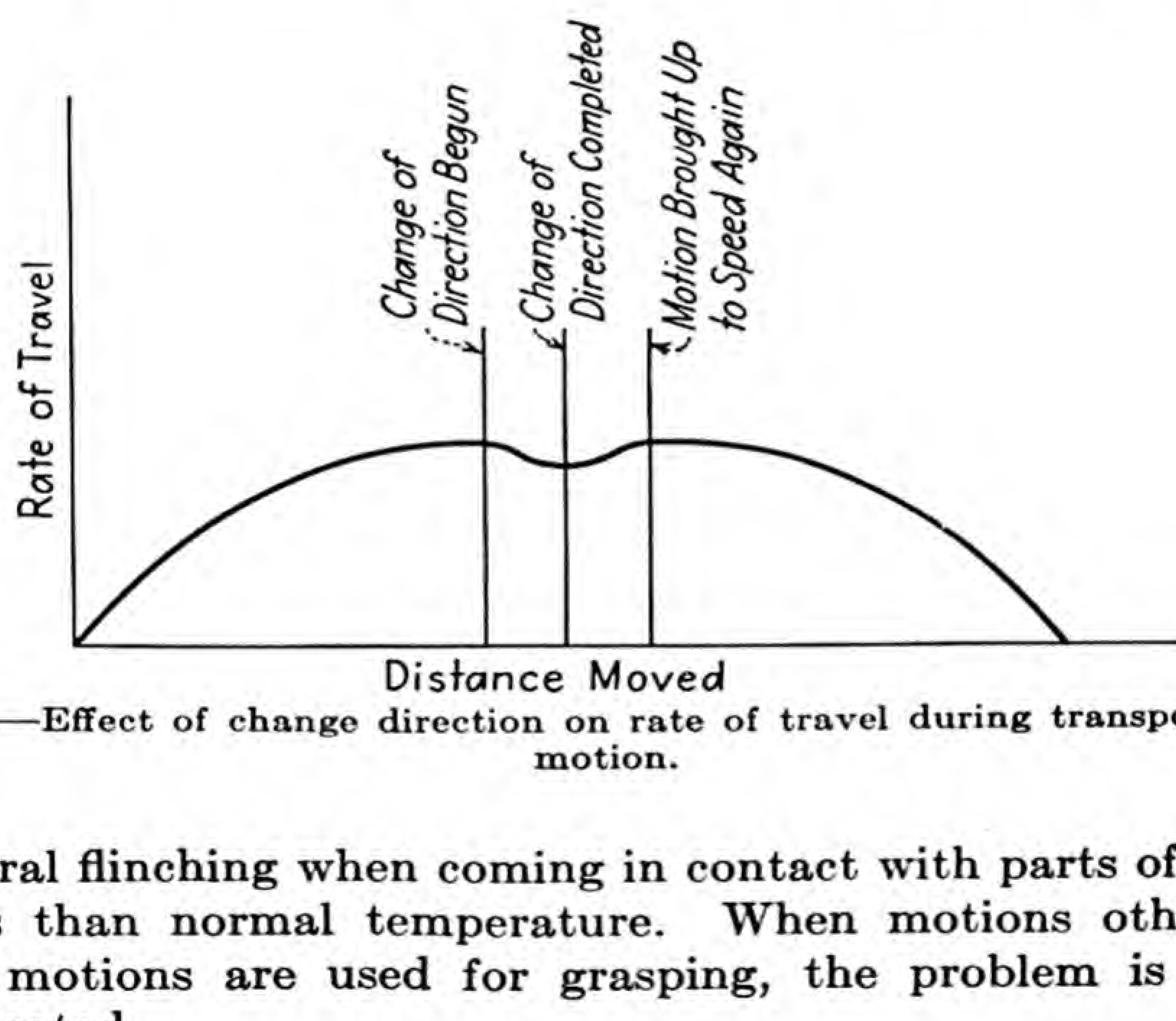


FIG. 65.—Effect of change direction on rate of travel during transport empty motion.

a natural flinching when coming in contact with parts of greater or less than normal temperature. When motions other than finger motions are used for grasping, the problem is further complicated.

The time for the *hold* basic division depends upon what the other bodily parts are doing. If physical movements are being made to which predetermined time values can be applied, the time for hold can also be predetermined. If the hold accompanies a plan, delay, or other indeterminate basic division, the time cannot be predetermined.

Release is usually a very quick motion if the grasp is not complicated. Release usually begins as soon as the finger motion is started and ends before it is completed. The actual release time is thus half the time for a finger motion or less. When drop

delivery is used, the part is often released during a transport motion, and hence the time for release need not be considered.

Pre-position is usually combined with some other motion, usually a transport loaded. In this case, the time for performing it need not be considered. If it is performed as a separate operation, analysis will show the motions used to which predetermined time values may be applied.

For a given degree of skill, the time for *position* varies with a number of factors, chief of which is the accuracy with which the part must be positioned. For example, assume that a No. 70 cotton thread must be inserted in a hole. The end of the thread must be positioned in line with the hole before it is pushed through. If the hole is 1 inch in diameter, the positioning may be done quite rapidly. If, however, the hole is very nearly the same size as the thread, as in the case of the eye of a needle, the positioning motion requires a great deal of control and hence will take much longer. Positioning time may be reduced in many cases by eliminating or reducing the element of control. In the example just cited, if a funnel-shaped guide is placed before the small hole, as shown by Fig. 66, the thread may be inserted in the small hole as quickly as it could in a large one. The guide furnishes the control and relieves the operator of the necessity of positioning accurately.

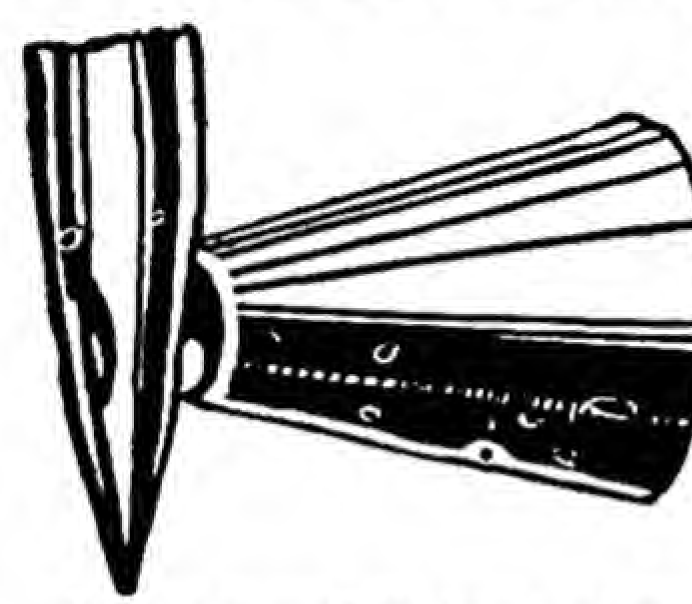


FIG. 66.—Guide to eliminate positioning when threading needle.

Weight and size also affect positioning time, very heavy and very small parts being more difficult to handle accurately. In general, it is difficult to predetermine time for positioning because of the variable control element which affects it so greatly.

Search and select are basic divisions for which it is difficult to predetermine time with exactness. Usually, if it is profitable to make a study in sufficient detail to recognize search and select, it is profitable to devise some mechanical means of eliminating them from the cycle. When the search consists merely of locating visually one part in a number which are lying together so that it may be grasped without fumbling, the reactions involved are similar to those for the inspect division. Select is rather indeterminate and is usually difficult to time or even to recognize. If an actual selection is made by trying a number of parts in succession

until one is found that fits, other basic divisions of accomplishment are employed. If the selection is made in the mind of the operator, it usually appears as a hesitation or a fumbling. In this case, it is more like a kind of plan, and if there is no real reason for making a selection, it will disappear from the cycle as the skill of the operator increases.

Plan, the basic division, is an operation for which it is impracticable to establish a predetermined time as such. It is a mental process and is largely dependent upon the mental ability and the experience of the operator. As has already been pointed out, there are two sorts of planning. The first is the planning which is done when the set-up is made. It involves the mental work which is performed when determining what must be done, devising the set-up, laying out the work place, and establishing the method. Quite often, this planning is done by more than one individual.

The second type is the mental work which the operator does as he performs the each-piece cycles. It does not occur at any one point, but goes on more or less during the entire job to an extent which depends upon the length and complexity of the operation, the experience and ability of the operator, and the repetitiveness of the job.

The first type of plan is difficult to measure exactly. On work of the same general nature, such as milling-machine work, a fair average value can be obtained for "study drawing per operation," which is a planning operation and usually the only one which occurs as a separate operation on work of this nature. When it comes to such planning as that involved in laying out the sequence of operations on a new line of work, arranging efficient layouts for bench work, and devising new tools and fixtures, practically no attempt to measure and predetermine planning time has yet been made. This is work of a creative nature upon which considerable original thinking must be done. If sufficient of this work of a similar nature existed, fair averages could undoubtedly be established, but usually the conditions surrounding mental work are so varied that it would be of little value to attempt to measure it.

Inspect appears as a hesitation while the sense organs note the characteristics of the object being inspected. The time for inspection depends upon the manner of inspecting and the characteristics of the part. The most commonly encountered method

of inspection is the visual method. Here the eyes look at the part, noting defects, colors, tool marks, or other points. Visual inspection can often be made while another basic operation such as transport loaded is being performed. If the inspection must be performed as a separate operation, motion-time standards are of no value. A separate study of the inspect operation, however, will yield time data which are useful under certain conditions.

The time for the *use* basic division is commonly determined by time study or from formulas based upon time study. If *use* is performed by purely physical motions, the predetermined times can be applied, but this is not often the case. *Use* is commonly determined by time study or from formulas based upon time study.

Predetermined time values can be applied to some kinds of *assemble* but not to others. Quite often, on assemblies, other variables affect assembly time besides the motions employed. For example, consider the simple operation of running a nut onto a stud with a finger motion as illustrated by sketch *B* of Fig. 47. If the nut fits quite snugly, it will turn only when the finger is directly in contact with it and will thus advance only about one quarter of a turn per finger motion. If the nut fits more loosely, it will keep on turning after the finger has passed by it and hence will be run down with fewer finger motions. The time for this can still be predetermined by counting the number of finger motions required, if there is no pause or hesitation between each motion. If, however, the nut fits very loosely, the finger will give it a spin. The finger will then wait until the spinning has slowed down before making another movement. The waiting time can only be predetermined by measurement, and hence in this case assembly time could not be predetermined solely from a knowledge of motion times. The same remarks apply to disassemble.

The time for the *balancing delay* for one bodily part can be predetermined if the time for the motions of the other bodily parts can be predetermined. The same is true for *unavoidable delays.* The time for all other delays cannot be predetermined from a knowledge of motion times. *Fatigue delays* usually appear as a lack of motion, and the causes and extent of *avoidable delays* are never known in advance.

Use of Motion-time Standards.—It is evident that the motion-time standards determined by a study of motions made

with maximum effort and minimum plan and control can seldom be met in actual practice. The minimum times can be converted to average or normal times by applying the leveling principle explained in Chap. XIX, but there are few operations, if any, which do not call for more plan and control than was used to establish the data.

In spite of this, however, motion-time standards have several important uses. Since the predetermined times show the relative value of motions, they can be used to determine which of two or more methods is the most efficient for performing a given operation. The total predetermined time for each method may be worked out, and the results will show at once which method is the best.

On most classes of work, the plan and control factors are fairly constant. Their amount quantitatively may be determined by comparing the time value arrived at by applying motion-time standards to the basic operations performed on a given job with the time value determined from time study. This latter value may be from a few per cent to 1,000 per cent or more higher than the former. Once the amount has been determined, however, it can be used with reasonable accuracy to determine time allowances from motion-time standards.

A variation of this method is as follows: Assume that an accurate time value, $T1$, has been established on a certain operation by time study and that a time value, $T2$, must be established on a similar operation. An operator process chart of the first operation is drawn up and motion-time values are assigned to each basic operation. The sum of these gives a time, $M1$. Then, a process chart of the second operation is drawn up in the same way and a time, $M2$, is determined. If the influence of plan and control is the same on both operations, the correct time allowance for the second operation can be computed from the proportion:

$$T1 : M1 = T2 : M2,$$

or

$$T2 = \frac{T1M2}{M1}.$$

This method is useful where exact estimates must be made on new work.

Most operations involve other than purely physical motions. In order to establish time values using predetermined time standards only, attempts have been made to establish a fixed relationship between the accurately measurable physical basic divisions of accomplishment and the less definitely measurable divisions such as pre-position, position, search, and select. It is then possible to establish time values on all work where the time for use and assemble are known and where control and plan factors have been established. The relationship is empirical, however, and involves the use of so many averages that it cannot be considered exact. When it is necessary to establish time values on a varied line of work, time formulas are more accurate and are much easier to apply.

At the present time, it seems that the predetermined time standards are more valuable throughout general industry in other connections than the establishing of time standards. In the first place, knowing the relative value of all physical motions, it becomes an easy matter to make efficient workplace layouts. This same knowledge when applied to machine design leads to better designs from an operating standpoint. In the shop, time-consuming motions are readily recognized by anyone possessing an understanding of the relative value of motions.

The chief value of the study of motion and motion times lies in the fact that a new approach is opened for methods studies. Points which might otherwise be overlooked or neglected are recognized as the result of the viewpoint developed from a detailed study of the characteristics of physical motions. This alone is sufficient to make a knowledge of motion times an exceedingly valuable tool for the time-study man.

CHAPTER X

TAKING MOTION PICTURES FOR MOTION STUDY

The human eye is a poor observer of fast motions. Hence, on operations where fast motions are made, it is often difficult to comprehend exactly what is taking place. In order to assist in determining what is occurring on operations of this kind, Frank B. Gilbreth instituted the procedure of taking a motion picture of the operation and then studying the resulting film in great detail. The procedure for doing this will be described in the next chapter.

The motion picture has since been found valuable for other industrial uses besides film analysis. For motion study work, for example, it has been found that a better study can be made by observing a motion picture of the operation than by observing the operation itself, even when the picture is projected at normal speed. In addition, motion pictures are useful for both employee and supervisory training and are probably used in this connection by industry even more than for detailed film analysis.

Because of the undoubted value of motion pictures for industrial use, the time-study man in the progressive plant may be called upon to take such pictures. Therefore, an understanding of the procedure to follow in this work will be a valuable adjunct to his other information. With the equipment at present available, the taking of satisfactory industrial motion pictures is a fairly simple matter, and no one need shrink from it because of lack of previous photographic experience.

Size of Film.—If motion-picture equipment is not already available, it must be obtained, and the first decision which must be made is the size of film to be used. Motion-picture film comes in widths of 8 mm., 16 mm., and 35 mm. In general, the larger the film size the clearer is the picture which is obtained and the higher is the cost of the film and equipment. For theatrical purposes, 35-mm. film is used. For industrial purposes, however, its high cost plus the cumbersomeness of the camera and projec-

tion equipment have limited its use largely to sales promotion films which must be projected in large auditoriums.

The film sizes between which choice must be made for motion study work are, therefore, the 8 mm. and the 16 mm. The advantages of 8-mm. film lie in low cost both of film and equipment and the ease with which the small, light equipment involved may be handled. The chief advantage of the 16-mm. size is the superior pictures which are obtained. Besides possessing somewhat greater sharpness, 16-mm. pictures can be projected to much larger sizes than the 8-mm. pictures. Since the cost of motion pictures is usually small in comparison with the results obtained, the advantages of the 16-mm. film, in the opinion of the authors, offset those of the 8-mm. film.

Motion-picture Equipment.—The equipment needed for industrial motion-picture work may be listed as follows:

1 camera with turret head for mounting three lenses.
1 *f* 1.5 lens in focusing mount.
1 15-mm. wide-angle lens.
1 additional lens chosen for any special conditions for which the other lenses are not suited. For example, if many outdoor pictures are to be taken, an *f* 2.7 lens will be desirable, while, if close-ups in hard-to-get-at places are wanted, a telephoto lens will be found useful.
1 metal tripod with tilting and panoraming head.
2 No. R2 photoflood lamps with self-reflectors.
1 exposure meter for determining proper exposures.
1 projector with hand crank and frame counter attachment.
1 portable screen 20 by 27 or 39 by 52 inches.
1 combination film rewinder, splicer, and editer.
1 loop attachment for continuous projection.

In addition to the above, a microchronometer is sometimes used. This is a high-speed timer which is placed in the field of the camera and photographed simultaneously with the operation.

Motion-picture equipment is constantly being improved, and any discussion of specific apparatus is certain to get out of date quickly. Therefore, the following remarks concerning the various items of equipment deal with the fundamentals of operation which have been found to be most important in motion study work. The illustrations show some of the equipment which is available at the present time.

Camera.—The camera is perhaps the most important piece of equipment, for upon it depends the results which will be obtained. The camera should be a variable speed camera, carefully governed

to run at constant speed, light enough to be readily portable, and capable of exposing a reasonable amount of film without interruption. Some of these specifications conflict. For example, a camera driven by a synchronous motor is available which runs at constant speed and which will expose as much film as the camera will hold without interruption. Due to its bulkiness, however, and the fact that it must be used close to a source of suitable

FIG. 67.—Bell and Howell 16-mm. 70-DA Camera with turret head.

current, its portability is impaired. For these reasons, the conventional type of spring-driven camera is most commonly used.

In selecting a camera, a large number of makes at varying prices will be found available. The point which should be most carefully checked is the ability of the camera to maintain its rated speed during the full time which it runs. The less expensive cameras have a tendency to slow down as the driving spring unwinds. Where a microchronometer is not used, time is measured by counting frames of film, as will be explained presently. Therefore, it is of paramount importance that the film be exposed at a known and constant rate, if the time element is to be measured correctly later on.

A camera which meets most of the specifications given is shown by Fig. 67. It has seven speeds, ranging from 8 to 64 frames per second. At normal speed of 16 frames per second, it will run for approximately 1 minute per winding, and during this time the makers guarantee that it will maintain its speed within plus or minus 5 per cent. A hand-cranking or synchronous motor attachment may be obtained if many operations of greater than 1 minute's duration are to be photographed.

Lens Equipment.—The lens is the eye of the camera, and as such, it must be of the highest quality. Lenses are identified by focal length and *f* stop numbers, as for example, a 1-inch *f* 1.5 lens. Lenses are equipped with an iris diaphragm which regulates the amount of light admitted to the camera just as the pupil of the eye, by expanding and contracting, regulates the amount of light which reaches the retina. The maximum amount of light which may be admitted when the iris diaphragm is opened to its fullest extent is indicated by the *f* stop number. An *f* 2.7 lens, for example, admits more light when fully opened than an *f* 3.5, and an *f* 1.5 admits still more. A lens with a low *f* stop number is said to be a "fast" lens. Because it admits more light to the camera, it can be used where less light is available than can a slower lens. Most industrial pictures are taken indoors. Many of them are taken under adverse conditions, as, for example, where darkly painted machines covered with grease (thus absorbing light rather than reflecting it) form the background. Thus, a fast lens is essential.

The focal length of the lens governs the area which will be included in the picture at a given distance from the camera. The lower the focal length, the greater is the area which is covered. A focal length of 1 inch is the most commonly used. However, under industrial conditions, it is often not possible to get far enough away from the operation being photographed to include all of the action in the field of the picture. Material, other machines, and the like may force the photographer to stand fairly close to the operation. In such situations, a lens with a shorter focal length known as a "wide angle" lens will be found useful.

Occasionally, the reverse of the condition just described is encountered; that is, the photographer cannot get as close to the operation as he would like in order to get details. For example, he may wish to photograph a close-up of the hands of the operator working in a limited area but, in order to do so, he would have to

place his camera so close to the operator that it would be in his way or at least would introduce an element of disturbance. To avoid this and still obtain the desired results, a telephoto lens may be used. These are available on 16-mm. equipment in focal lengths up to 6 inches. The greater the focal length, the farther away from the object can the picture be taken. High focal-length lenses, however, are usually slower than the 1-inch lens.

Tripod.—The most satisfactory results from a quality standpoint are obtained if the camera is held absolutely steady during the taking of the picture. A tripod rigidly built will assist in

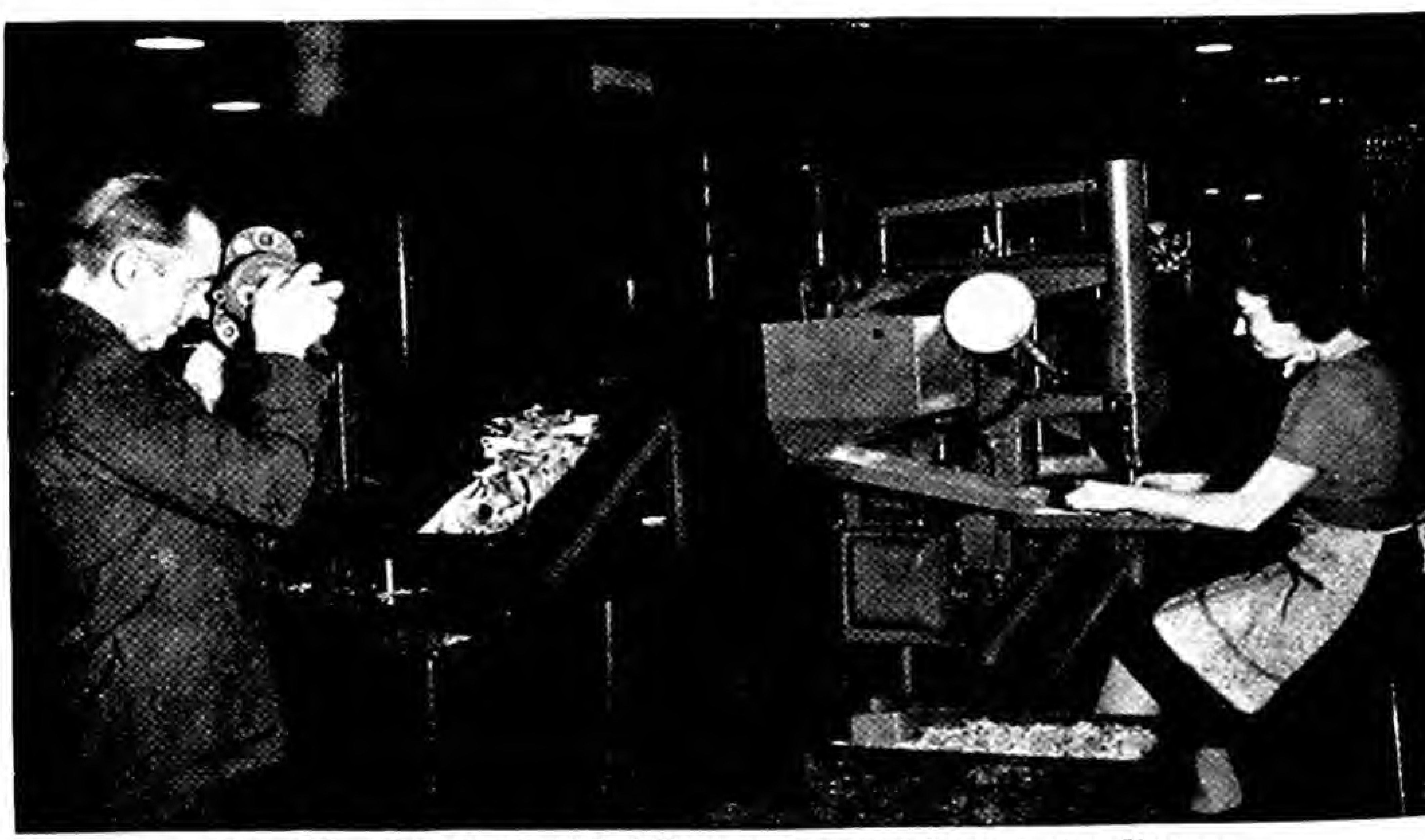


Fig. 68.—Method of holding camera to insure steadiness.

giving this steadiness, provided the floor on which it rests is not vibrating. If the tripod is equipped with a tilting and panoraming head, the camera may be moved if necessary to follow the action of the subject.

Under industrial conditions, it is often difficult to use a tripod. In order to include all of the action in the scene, the photographer sometimes has to get above floor level and look down upon the operation. In other cases, congestion makes it difficult to find room to set up the tripod. In cases of this kind, the camera must be held in the hand. If certain precautions are observed, tripod steadiness can be approached. Figure 68 shows the proper method of holding the camera. The camera is grasped firmly by the left hand. It is held against the forehead and nose of

the photographer to support it further. The arms are held against the body. If, in addition, the photographer can brace his body against some solid support, still greater steadiness will be obtained.

With a little practice, steady pictures may be taken in this manner. When skill has been acquired in doing this, many photographers prefer to dispense with the tripod altogether, feeling that the slight additional steadiness does not offset its cumbersomeness and the time required to set it up.

Exposure Meter.—The most important accessory for motion-picture work is the exposure meter. This is an instrument for

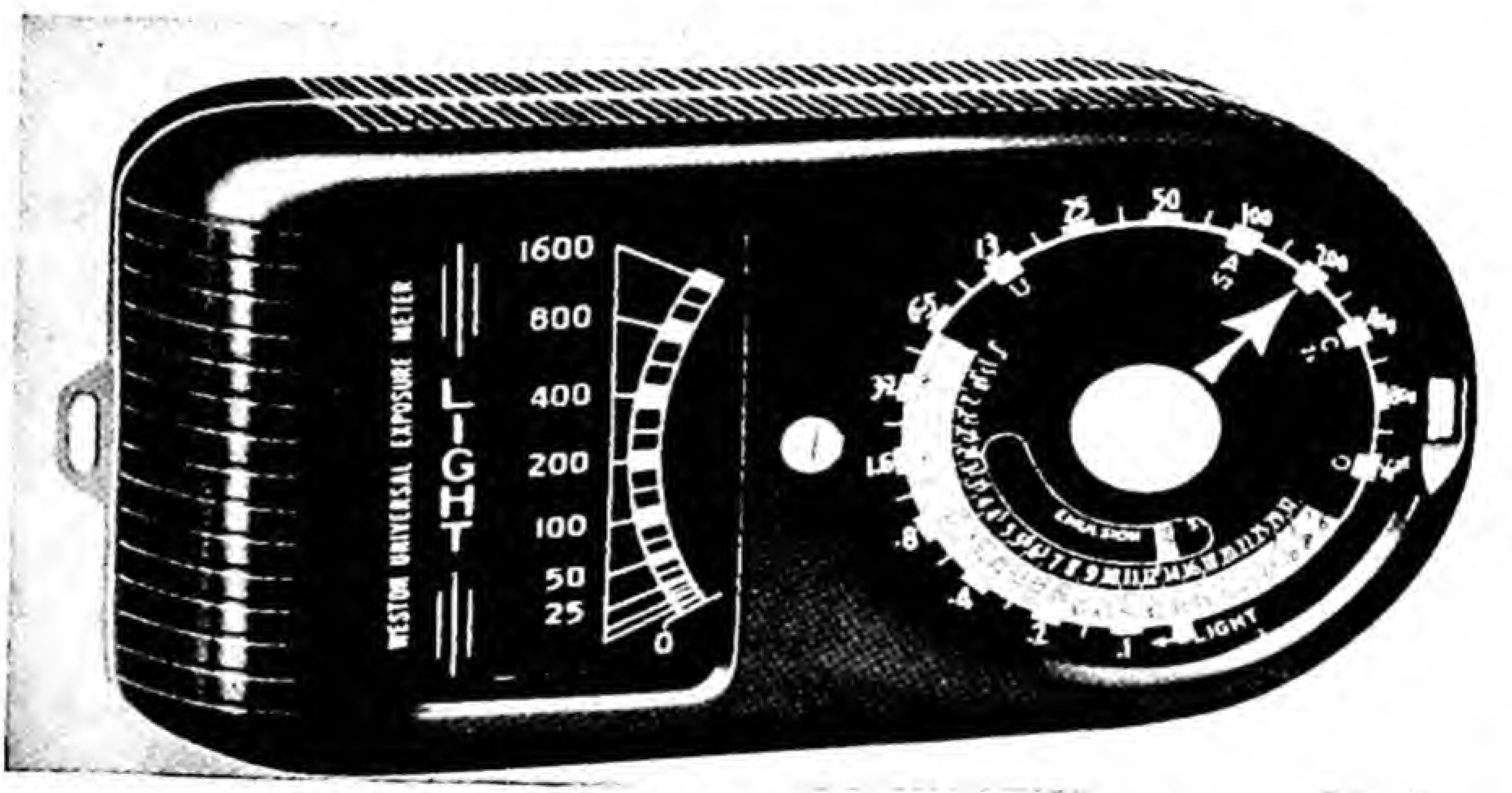


FIG. 69.—Weston Master Exposure Meter.

measuring the amount of light reflecting from the object being photographed. An exposure meter of the photoelectric cell type is illustrated by Fig. 69. To use it, the meter is held close to the object to be photographed. Light reflecting from the object energizes a photoelectric cell inside the meter, and an indicating hand shows the intensity of the light. A kind of circular slide rule attached to the exposure meter is then used to determine the correct iris diaphragm opening for the shutter speed of the camera and the sensitivity of the film being used.

Because of the improvements in film and exposure meters which are made frequently, no explanation of the use of the meter other than that given above will be made, for specific directions would soon become out of date. Complete directions accompany the meter when it is purchased and give detailed instructions for its use. It will suffice to say here that it is relatively easy to use

an exposure meter, and that it will quickly pay for itself through the elimination of film spoilage due to improper exposure.

Supplementary Lighting.—Where there is good daylight lighting near windows or under skylights, satisfactory motion pictures can be taken using modern highly sensitized film without supplementary lighting. Away from windows, however, additional lighting is desirable. With the highly sensitized films, pictures can be taken with surprisingly little light, but the clearness and detail of the picture will be increased by supplementary lighting.

Lighting equipment has so improved that good lighting is no longer a problem. Figure 70 shows a No. R2 Photoflood bulb with reflector built in. These bulbs can be screwed into available

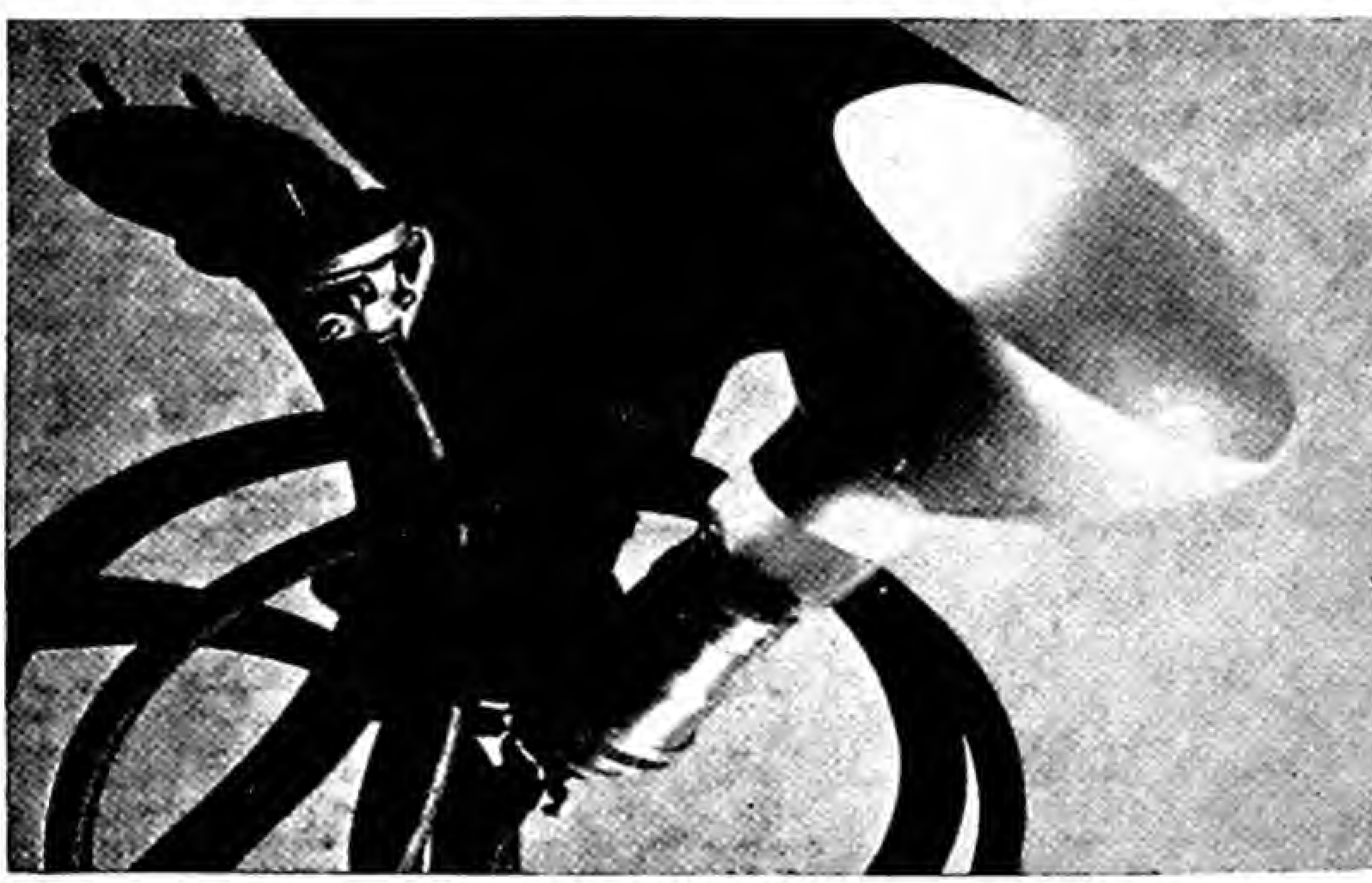


FIG. 70.—Photoflood bulb with self-reflector.

light sockets or used in the conventional extension and give an illumination equivalent to a 1500-watt tungsten lamp. Two of these lamps will be sufficient to illuminate the average industrial picture.

Combination Rewinder, Splicer, and Editer.—After pictures have been taken, the film often needs editing before it can be shown. Undesirable parts must be cut out, the continuity may be changed, and sometimes titles are inserted. The combination rewinder, splicer, and editer shown by Fig. 71 is used in this connection. The film-editing attachment *A* consists of a magnifying optical system and an incandescent bulb in a hood to illuminate the film beneath the magnifier. The splicer *B* attached to the base is for cementing film together after breaks, insertion of titles, or deletion of parts of film.

Projector and Accessories.—A good projector is desirable for showing the motion pictures after they have been taken. For normal-speed projection, the type of projector used by amateur motion-picture enthusiasts is satisfactory. For detailed frame-

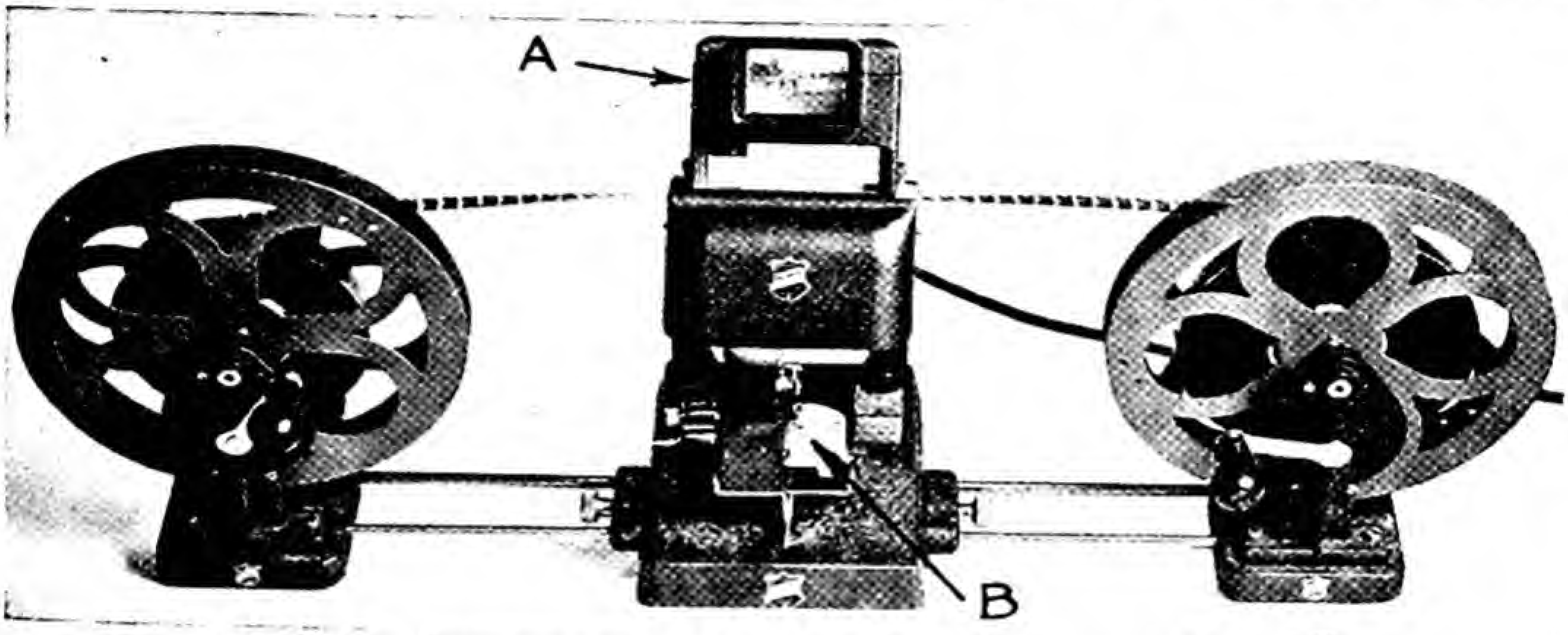


FIG. 71.—Combination film rewinder, splicer, and editer.

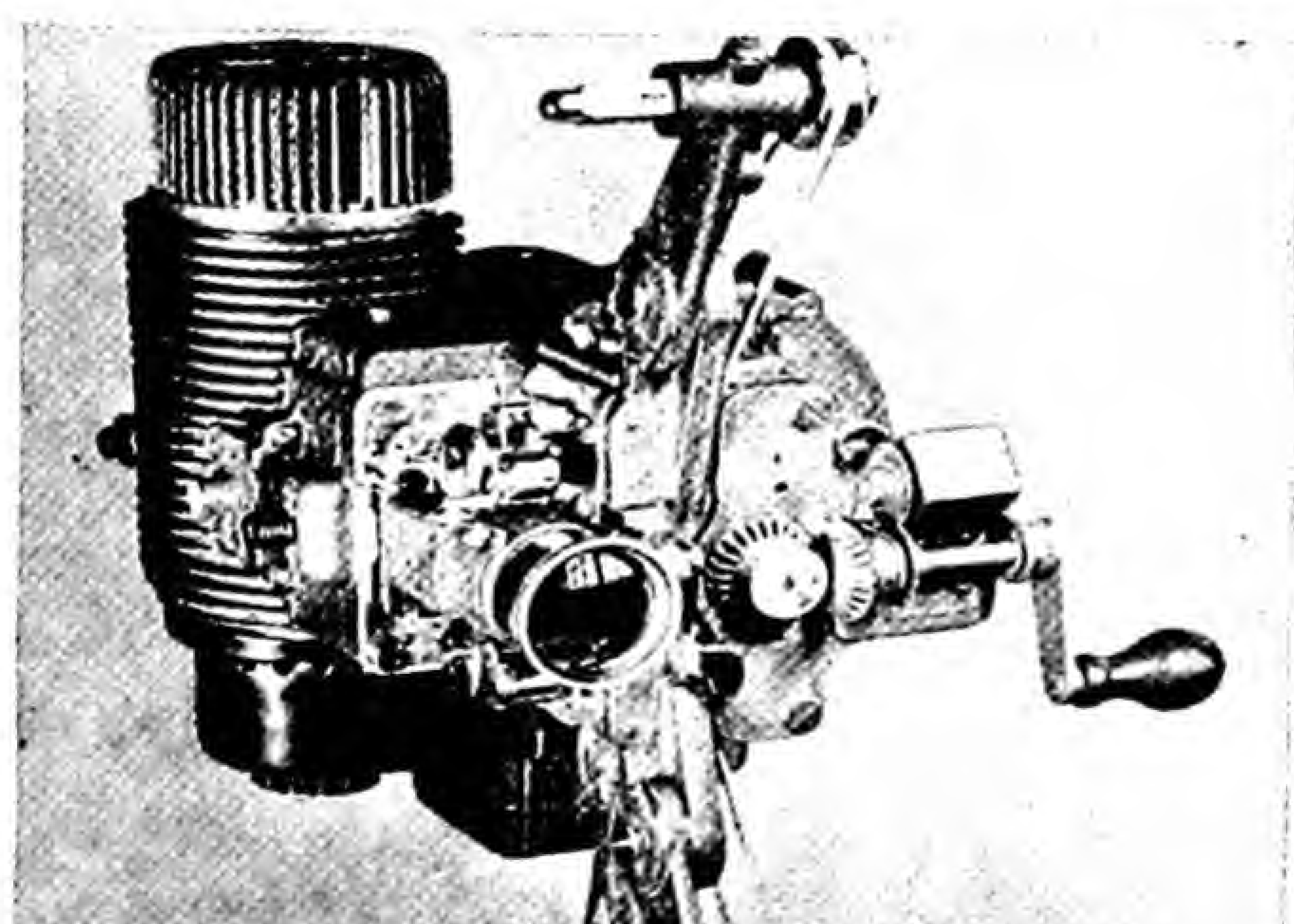


FIG. 72.—Bell and Howell projector with hand crank and frame counter attachment.

by-frame analysis work, however, a method of moving the film through the projector a frame at a time must be provided. The hand-crank attachment shown in Fig. 72 is one accessory for accomplishing this. Each revolution of the crank moves the film one frame forward or backward, depending upon the direc-

tion in which it is turned. A counter indicates the number of frames which have passed through the projector.

Sometimes it is desirable to project a picture over and over again, so that it may be studied thoroughly. In order to avoid having to rewind the film and rethread the projector each time, a continuous projection attachment such as that shown by Fig. 73 may be used. The film is prepared by cementing the two ends together so that a continuous loop is formed. Then, the film is placed on the continuous projection attachment, where it will run continuously without further attention.

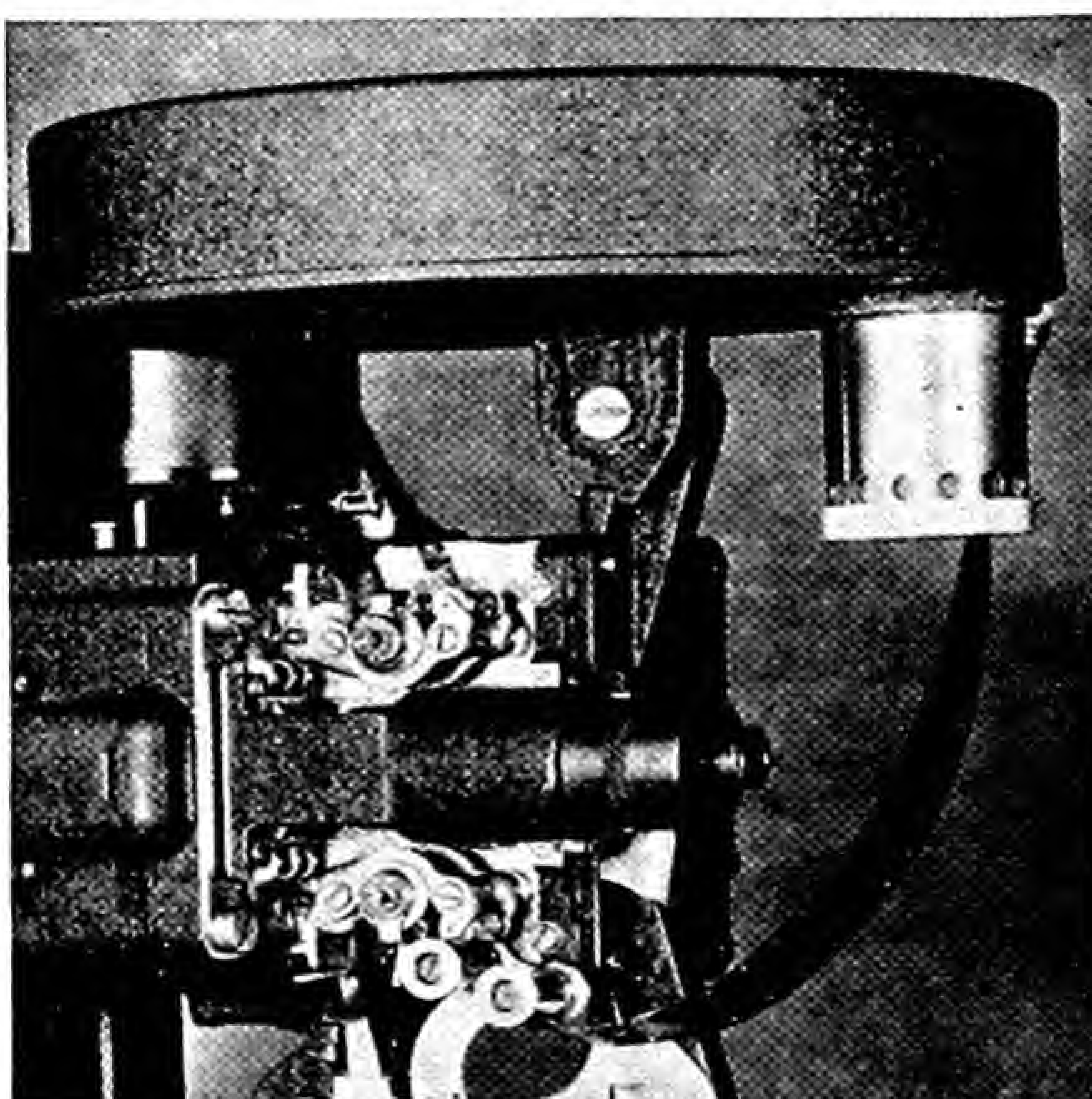


Fig. 73.—Continuous projection attachment.

A projection screen completes the necessary motion-picture equipment. The screen should be portable, for it will probably be moved frequently. Its size will depend upon the maximum size of the group which will view the pictures at one time. A small group can use a small screen, but larger groups need larger screens, so that the magnification is great enough to permit those far from the screen to see the picture clearly.

The Microchronometer.—It is sometimes considered desirable to record time simultaneously with the taking of the picture. The most successful way of accomplishing this is to place a high-speed timer in the field of the picture and photograph it along

with the picture. Figure 74 shows a well-designed microchronometer. It consists of a synchronous self-starting motor with geared movement. Three interchangeable, non-reflecting, aluminum dials are furnished. The smallest dial is used for close-up shots, the medium dial for normal shots, and the large dial for distance shots. Three interchangeable sets of aluminum hands in dull white finish are furnished to match the dials. The com-

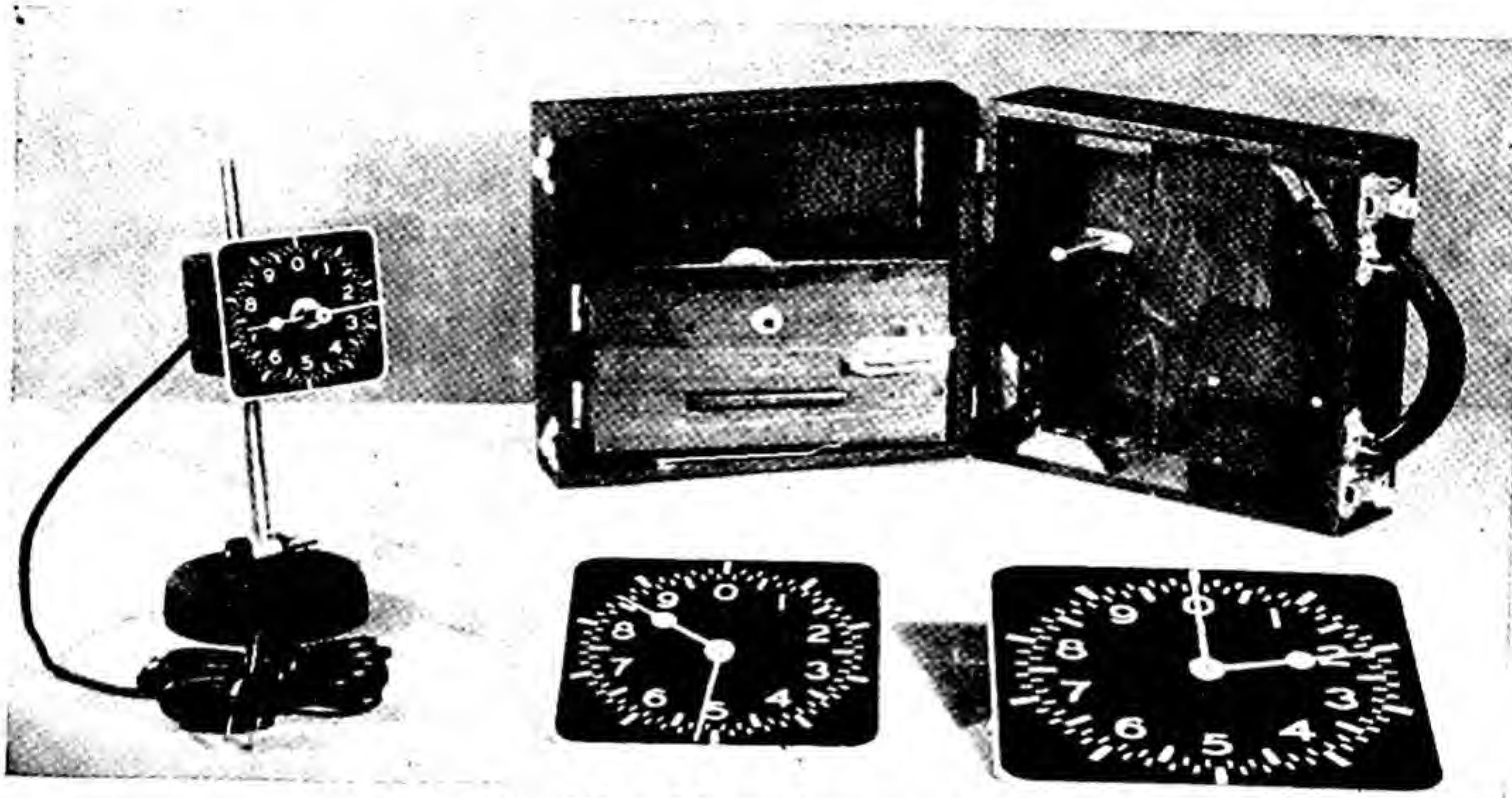


FIG. 74.—Microchronometer.

plete outfit including cable, base, and stand fits into a wooden carrying case.

Taking Motion Pictures in the Factory.—When familiarity with the equipment has been achieved, the taking of motion pictures in the shop is quite simple. After one or two pictures have been taken, the procedure becomes more or less routine to all concerned and causes little or no disturbance. Using the excellent modern equipment which is available, after a little practice, pictures which approach professional standards of quality may be obtained by those having little or no previous experience.

Most operators rather enjoy having their pictures taken and will cooperate wholeheartedly, especially if care is taken to avoid embarrassing the subject in any way and to make the whole procedure seem matter of fact. When female operators are to be photographed, it is usually desirable to give them a day's notice so that they may have an opportunity for preparing their appearance to their own satisfaction. When an operation has been

selected for photographing, the operator should be approached in a straightforward manner, and the purpose of taking the picture should be explained.

The scene to be taken often looks different through the view-finder of the camera than it does to the unaided eye, and therefore the angle from which the picture is to be taken should be decided upon only after studying the scene carefully through the view-finder. An attempt should be made to see that the hands of the operator are in the field of the camera at all times. If the operator is working at a machine like a punch press, where it is impossible to take the picture from in front of the operator, this may not always be possible. Next in desirability to the front position is a position to one side of the operator. Another position sometimes used is from the top looking down. The nature of the operation, the nature of the work place, and the congestion around the work place will determine the position from which the picture will be taken.

In addition to keeping the hands of the operator in the picture, some thought should be given to the composition of the scene. Although the movements of the hands are the chief factor to consider, pictures which show the hands only are rather uninteresting to watch. Therefore, it is usually advisable to attempt to include the head and trunk of the operator in the picture.

When a proper position has been selected, the lighting should next be considered. Measurement with the exposure meter will show whether or not supplementary lighting is necessary. If it is, the photographer must see that it is properly placed. Two lights, one on either side of the operator, usually give more pleasing results than a single light or two lights on the same side of the operator. The lights should be kept out of the field of the camera and should never be permitted to direct light toward the camera. Wide latitude in the placement of lights is permissible, if these few simple rules are kept in mind. Deep shadows should be avoided at any point of the work place where work must be done. Photographers with a sense of the artistic will endeavor to adjust the lights so that the most pleasing effect is obtained, but a discussion of this matter is beyond the scope of this book. If the lights are used on extension cords, they can be moved about at will. In this case, one or two assistants will be required to hold the lights. Usually the foreman and an operator can be requested to perform this service. Clamps are sometimes used

to hold the lights in place. Tripods are also available for this purpose, but they are usually rather cumbersome.

With the lighting arranged, the photographer should determine the distance from the camera to the central point of the scene, if a focusing lens is to be used. If the camera is less than 6 feet from the object being photographed, actual measurement with a rule or tape should be made. Distances greater than 6 feet may be estimated if the estimating is done carefully, although here, too, actual measurement is preferable.

The photographer is now ready to take the picture. After making sure that the camera is fully wound, he should get set in the position shown by Fig. 68. Then at some definite point, as when the hand of the operator starts for the next piece to be worked upon, he should begin taking the picture. This is merely a matter of pushing a button. He should continue to take the picture until he is sure that he has exposed enough film for his purposes. He should then endeavor to stop the camera at the same point in the operation cycle that he started it. This is not essential, but it will help if film loops are later to be made.

During the taking of the picture, the photographer should concentrate on holding the camera steady and in keeping the operator in the picture. If possible, a position should be taken such that the camera will not have to be moved during the filming of the scene. If the operator walks about, however, this is not always possible. In cases of this kind, the operator should be followed by the camera, and an attempt should be made always to keep him in the center of the picture.

Occasionally, it is desired to cover a wide area in a picture, to show a departmental layout or a group at work. If the area is greater than that which can be included in the field of the camera, a panoramic view must be taken. Panoramic views are at best rather unsatisfactory when projected on the screen. The usual tendency is to pam too fast. This causes a jumpy, blurred image. A motion-picture camera in reality takes a series of snapshots. Most people realize what happens when a snap-shot camera is moved at the moment the picture is taken. The same thing happens with a motion-picture camera if pamming is done too quickly. The best practice is to avoid panoramic shots altogether. If one must be taken, pamming should be done very, very slowly, moving the camera from left to right.

The length of the picture which is taken is quite important. Most inexperienced photographers tend to make scenes too short, in a desire to conserve film. This is false economy, for too short scenes are jerky and unpleasant to watch and hence are eventually discarded. Five feet of 16-mm. film or about 12.5 seconds of filming time should be considered a reasonable minimum. If the operation cycle is longer, the scene will, of course, be longer too, for at least one complete cycle should always be obtained.

The majority of operations which are ordinarily photographed in industry require less than a minute to perform, because repetitive operations are likely to be rather finely subdivided in accordance with the principles of the division of labor. From time to time, however, longer operations are encountered. Since the best spring-driven cameras operate only approximately 1 minute per winding, it is then necessary to film the scene in two or more shots. However, continuity of action in the finished picture can be obtained as follows: As the camera runs down and stops, the exact position of the hands of the operator should be noted. While the camera is being rewound, the operator is permitted to complete the piece he is working on and begin the next piece. When he comes to the point in the cycle where the camera stopped on the preceding piece, the camera is started again. This procedure is repeated until a complete cycle has been photographed. When the developed film is projected, if the filming has been carefully done, it will appear as though the photographing had been done without interruption.

Conclusion.—8-mm. and 16-mm. motion-picture equipment has been developed largely for the use of amateur motion-picture enthusiasts. Hence, it has been made simple and rugged. Anyone can learn to take reasonably good pictures after a few instructions, and dealers in photographic equipment are always glad to give information and advice. In this chapter, an attempt has been made to outline the general procedure which has been found suitable for taking industrial motion pictures. Specific details are left for the makers of the equipment purchased.

CHAPTER XI

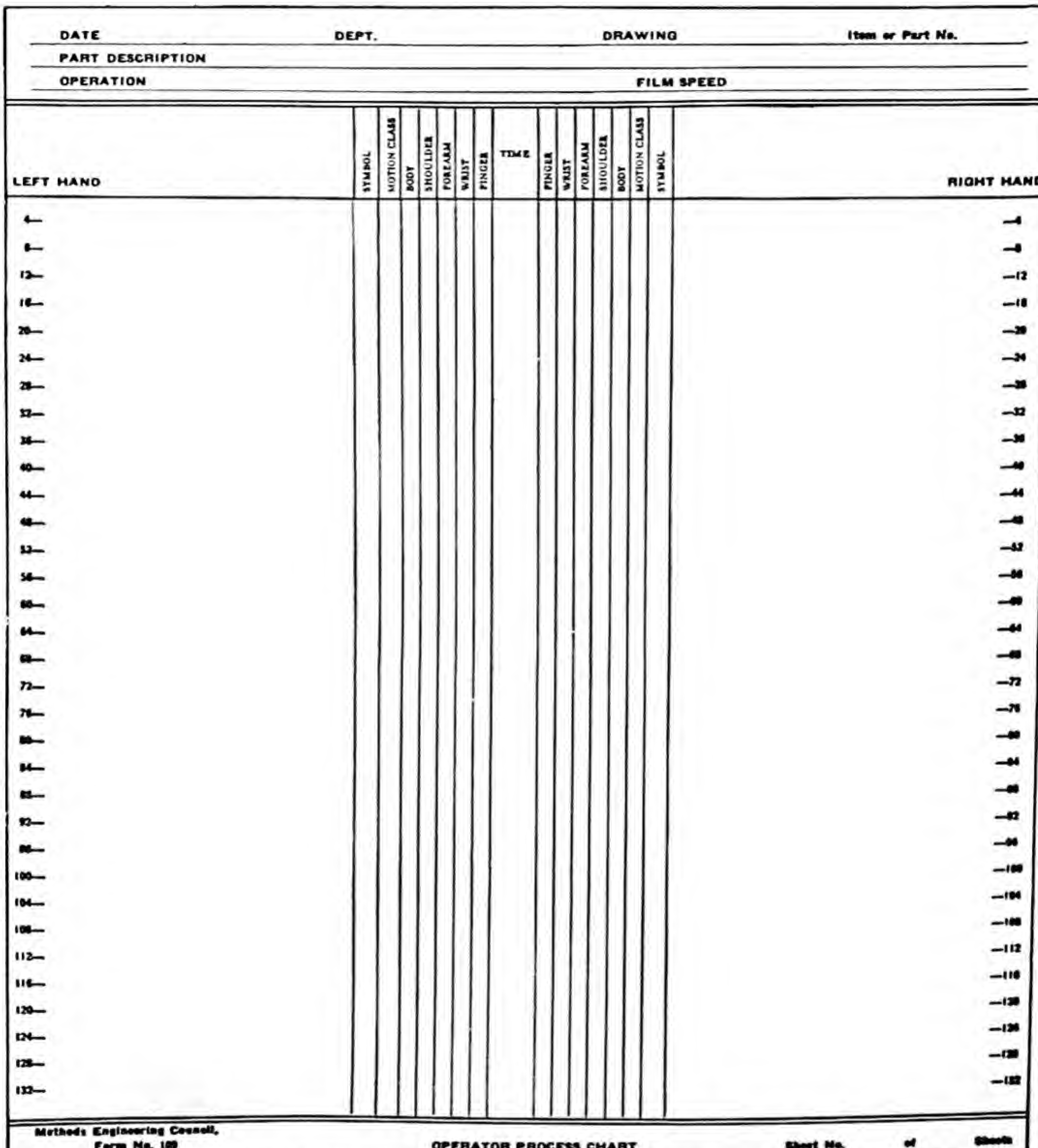
FILM ANALYSIS PROCEDURE

The frame-by-frame analysis of a motion picture yields a great deal of detailed data which it is difficult to obtain in any other way. It is estimated that about 10 per cent of all industrial work is of a highly repetitive nature involving a number of rapid hand motions, and on this type of work, the motion picture is a direct aid to making motion studies. The making of a film analysis is no easy task, however; therefore, a study of this kind should not be undertaken unless it is reasonably certain that the results will justify the labor involved.

For a large percentage of industrial work, only the most superficial motion study is practical because of small quantities, frequent design changes, and so on. On work of this kind, the making of motion pictures and the analysis of the film would be impractical. Even on stable, large-quantity jobs, it has been found that the majority of operations can be studied satisfactorily by analysis and observation without taking motion pictures. To do this successfully, however, the observer must be equipped with a thorough understanding of the basic divisions of accomplishment, the laws of motion economy and their corollaries, and the characteristics of motions, plus the power of accurate observation, and probably the quickest way of gaining these is by doing film analysis work. Therefore, it may be said that, in addition to furnishing a valuable means of studying certain types of work, frame-by-frame film analysis is useful for training time-study men to do motion study work by analysis and observation.

The Operator Process Chart.—In order that the information gained during the course of a frame-by-frame analysis of a motion picture of the operation under study may be available for study and reference, it is charted on an operator process chart. This chart may take the form of the simplified operator process chart shown by Fig. 41, or it may be an elaborate chart detailing exactly what is done by the fingers, hands, arms, trunk, head, eyes, legs, and feet of the operator. For most motion studies, an

operator process chart form in between these two with respect to elaborateness has been found to be most practical for the majority of operations studied. Such a form is shown by Fig. 75. It


DATE DEPT. DRAWING Item or Part No.
PART DESCRIPTION
OPERATION FILM SPEED

LEFT HAND	SYMBOL	MOTION CLASS	BODY	SHOULDER	FOREARM	WRIST	FINGER	TIME	FINGER	WRIST	FOREARM	SHOULDER	BODY	MOTION CLASS	SYMBOL	RIGHT HAND
4—																—4
8—																—8
12—																—12
16—																—16
20—																—20
24—																—24
28—																—28
32—																—32
36—																—36
40—																—40
44—																—44
48—																—48
52—																—52
56—																—56
60—																—60
64—																—64
68—																—68
72—																—72
76—																—76
80—																—80
84—																—84
88—																—88
92—																—92
96—																—96
100—																—100
104—																—104
108—																—108
112—																—112
116—																—116
120—																—120
124—																—124
128—																—128
132—																—132

Methods Engineering Council,
Form No. 109
OPERATOR PROCESS CHART
Sheet No. of Sheets

Fig. 75.—Operator process chart form.

provides space, first, for identifying the job and noting the camera speed at which the motion picture was taken, and then for charting the basic divisions of accomplishment performed by each hand and the motion class used for performing them.

To provide for greater ease of interpretation, space is provided for describing each basic operation in words and identifying it by its symbol. The motion class is given by number and is also portrayed by blocking in, in solid color, the columns headed finger, wrist, forearm, shoulder, and body. This blocking in makes it possible to ascertain at a glance whether or not the operation is balanced—that is whether both sides of the body are performing the same class of motion at the same time—and also to see quickly what class of motions predominates. By using different colors to block in the effective and the ineffective basic operations, a further impression of the effectiveness of the operation is readily obtained.

The vertical space on the chart allotted to each basic operation is determined from the number of frames of film required to perform that operation. The number-of-frames scale is given on the right- and left-hand edges of the chart. A time scale can also be inserted in the space provided at the center of the chart. If no timing device was included in the field of the camera when the picture was taken, the information given at the head of the chart concerning camera speed forms the basis for the insertion of the time scale. The standard 16-mm. motion-picture camera used by amateur photographers has a normal speed of 16 frames per second. Thus, every 16 divisions vertically on the chart represent 1 second of time. Since seconds are not commonly used as time units in methods work, it is usually preferable to insert a time scale in units of decimal hours or decimal minutes. This is quite simple to do: $\frac{1}{16}$ second is equal to 0.00001735 hour, for example. Therefore, during the course of 0.0001 hour, $0.0001 \div 0.00001735 = 5.76$ frames elapse. The table shown by Fig. 76 will be found useful for adding the time scale to operator process charts made from films exposed at either normal speed of 16 frames per second or slow-motion speed of 64 frames per second.

Sixteen-millimeter motion-picture cameras are available which operate at speeds which are multiples of 1,000 frames per minute. These speeds simplify the addition of time scales in terms of decimal minutes, but this does not offer enough of an advantage to be important. If many operator process charts are to be drawn, a time scale for the time units to be used may be prepared on a template from which the time scale may be quickly transferred to the charts as they are constructed.

Some engineers prefer to use a timing device, such as that shown by Fig. 74, in the field of the camera when the picture is taken. Then when the film is analyzed, the clock reading appears on each frame as it is projected. This gives time more accurately than the frame count, if one of the less accurately constructed

Decimal hours	No. of frames elapsed at camera speed of 16/sec.	No. of frames elapsed at camera speed of 64/sec.	Decimal minutes	No. of frames elapsed at camera speed of 16/sec.	No. of frames elapsed at camera speed of 64/sec.
.0001	5.76	23.04	.01	9.60	38.40
.0002	11.52	46.08	.02	19.20	76.80
.0003	17.28	69.12	.03	28.80	115.20
.0004	23.04	92.16	.04	38.40	153.60
.0005	28.80	115.20	.05	48.00	192.00
.0006	34.56	138.24	.06	57.60	230.40
.0007	40.32	161.28	.07	67.20	268.80
.0008	46.08	184.32	.08	76.80	307.20
.0009	51.84	207.36	.09	86.40	345.60
.0010	57.60	230.40	.10	96.00	384.00
.0011	63.36	253.44	.11	105.60	422.40
.0012	69.12	276.48	.12	115.20	460.80
.0013	74.88	299.52	.13	124.80	499.20
.0014	80.64	322.56	.14	134.40	537.60
.0015	86.40	345.60	.15	144.00	576.00
.0016	92.16	368.64	.16	153.60	614.40
.0017	97.92	391.68	.17	163.20	652.80
.0018	103.68	414.72	.18	172.80	691.20
0019	109.44	437.76	.19	182.40	729.60
.0020	115.20	460.80	.20	192.00	768.00
.0021	120.96	483.84	.21	201.60	806.40
.0022	126.72	506.88	.22	211.20	844.80
.0023	132.48	529.92	.23	220.80	883.20
.0024	138.24	552.96	.24	230.40	921.60
.0025	144.00	576.00	.25	240.00	960.00

Fig. 76.—Table of decimal hours, decimal minutes, and number of elapsed frames at camera speeds of 16 and 64 frames per second.

types of camera was used for taking the picture. The timing device, however, adds just one more factor to be considered at the time the picture is taken, and for this reason many engineers dispense with its use. In most motion studies, the important thing is what the hands are doing alone and in relation to one another rather than the exact time they are taking to do it. The

frame count gives the time accurately enough for most purposes, particularly when the camera shown by Fig. 67 is used.

Film Analysis Equipment.—The film analysis procedure consists of viewing, a frame at a time, a motion picture of the operation under study, analyzing it into terms of the basic divisions of accomplishment performed by each hand, and charting the information thus gained on an operator process chart. Besides the chart forms, therefore, all that is needed is a means of viewing the motion-picture film a frame at a time and of keeping track of the number of frames viewed. The ideal apparatus for motion-picture analysis work would be a single unit containing projection apparatus, viewing screen, and frame counter which could be operated by push-button control forward or backward a frame at a time. At the time of writing, no such apparatus is commercially available, although its development is being considered. Therefore, individual time-study men have been forced to design their own apparatus or to make use of available apparatus which is not so convenient as might be desired.

In the former category, two developments are worthy of description. One consists of a strip of clear film about 5 feet long, each frame of which is numbered consecutively, starting with one, with black India ink. This strip is formed into a loop by splicing the two ends together. The clear film strip is threaded into the projector together with the motion-picture film to be analyzed. It moves with the film through the projector and as a result each frame of the picture is shown on the screen with a number superimposed over it. In this way, any ordinary projector without a frame-counting attachment may be used for film analysis purposes.

The other development consists of a projector of the type shown by Fig. 72 mounted in a box with an optical system which reflects the picture back to a screen located directly in front of the analyst. The general arrangement is shown by Fig. 77. This set-up brings the picture close to the analyst where he can better study it in detail, and it may be viewed in a lighted room so that the charting work and the analysis work may be carried on without alternately turning the room lights on and off. The set-up is rather bulky, however, and therefore must be confined to one location.

The most commonly used apparatus consists of the conventional projector arranged for hand cranking. A frame counter is

not absolutely essential, for frames may be counted mentally as the hand crank is turned, but it makes the analysis work a good deal easier and increases the accuracy of the final results. The projector shown by Fig. 72 has been found satisfactory for film analysis work. This projector, together with a screen, a pad of operator process chart forms, a straightedge, and a pencil are all that is necessary for film analysis work. Of course, if a timing device was photographed when the picture was originally taken, no frame counter is necessary.

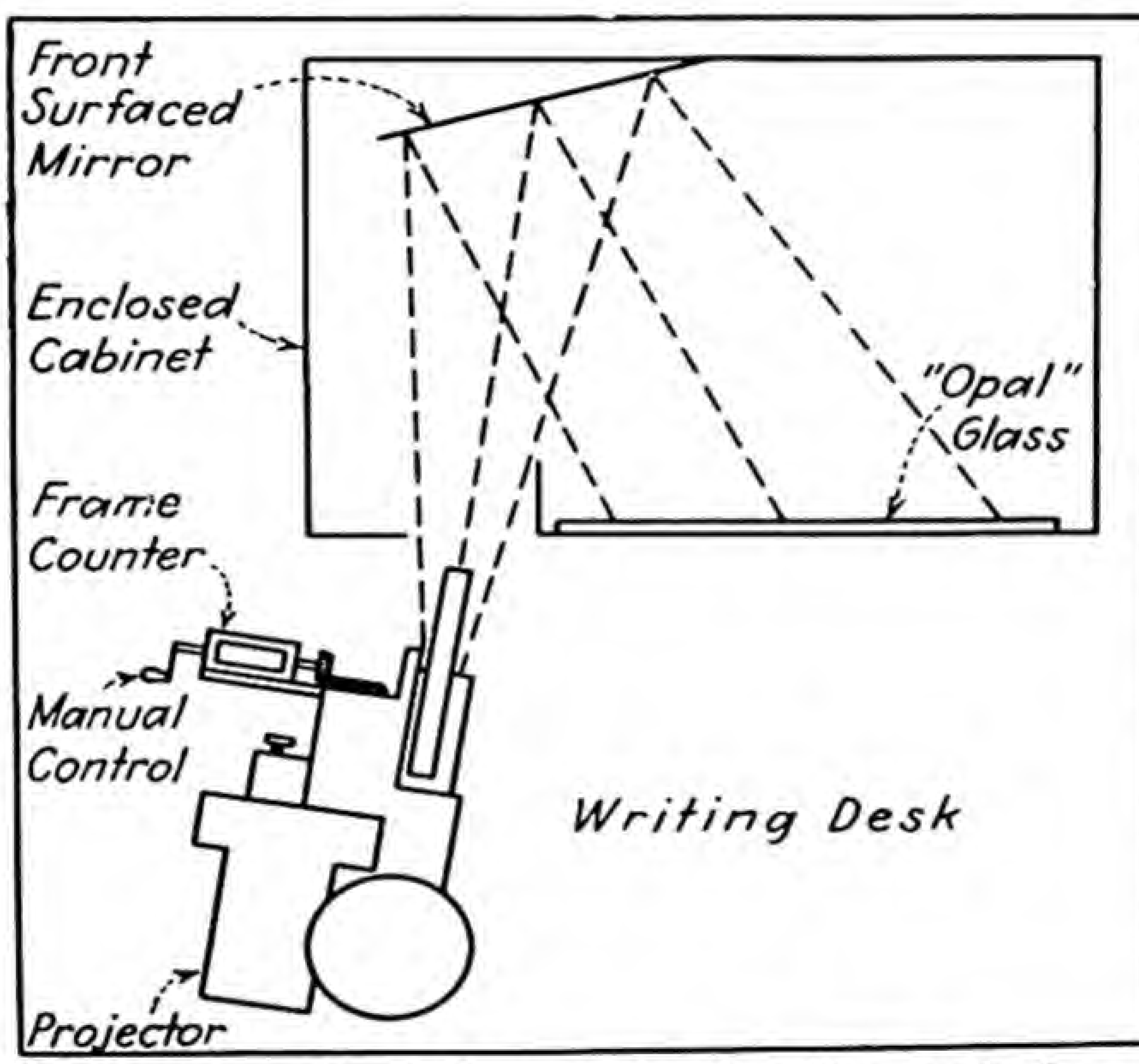


FIG. 77.—Special apparatus for film analysis.

Film Analysis Procedure.—Figure 78 shows a conventional set-up for film analysis work. The analyst is seated at a table before which is placed the screen. In front of and slightly to the left of the analyst is the motion-picture projector which he hand-cranks with his left hand. To the right of the projector is the operator process chart form on which he records the results of his analysis. Room lights may be turned off to view the film and on to do the charting work, or if the picture is sharp and bright, it may be possible for the analyst to view the picture in a subdued light which is strong enough to permit him to do the charting work.

The projector should be equipped with a fire screen which will protect the film from burning during the course of single-frame

projection. Even if the film does not burn, there is usually sufficient heat reaching it to dry it out considerably; hence, it is well to avoid leaving one frame before the aperture for unduly long periods. Turning the projector lamp off during periods of charting will help to protect the film.

To make a film analysis, the procedure described below should be followed. If more than one cycle of the operation has been photographed, the film should be run back and forth through the projector a few times at normal speed until the cycle which

FIG. 78.—Conventional set-up for film analysis work.

appears to be most nearly representative is selected. Cycles containing irregularities in performance should be avoided during the first stages of the analysis, for usually the analysis will suggest an entirely new method, and a study of the irregularities which occurred on the old method will be profitless. Eventually, when the best method which can be discovered at the time is installed, it may pay to photograph it and study any irregularities which occur, with the idea of effecting still further improvement by eliminating them.

With the cycle to be analyzed selected, the film should be stopped somewhere near the beginning of the cycle and then

moved to the exact starting-point by hand. The starting-point may be the moment at which the piece just completed is released or the moment at which the piece to be worked upon is grasped. Release and grasp usually consume only one frame at normal speed and hence offer a definite and easily located starting-point for the cycle. If because of the nature of operation some other starting-point appears more desirable, it may be used, for as long as at least one complete cycle is analyzed, the major objective of the analysis will be accomplished.

When the starting-point has been selected, the frame counter should be set to zero. The identifying information at the top of the chart should be filled in as completely as possible. The analyst is then ready to begin the analysis proper.

Either the right or the left hand and arm may be studied first, depending upon which one is performing the operation selected for the starting-point. The basic operation being employed is first determined. Then the film is slowly moved forward a frame at a time until the basic operation terminates. During this period, the motion class employed is noted and the operation is watched closely. Questions as to the necessity for the operation, the possibilities of improving it, and so on may be mentally asked at this time.

When the basic operation has been completed, the counter reading is noted. Then the information thus far obtained is recorded on the operator process chart. The point on the number-of-frames scale corresponding to the counter reading is first located. Then with a straightedge, a line is drawn from the edge of the time scale to the edge of the chart. Directly above the line is recorded a brief description of what was done. This is recorded in common terminology rather than in terms of the basic operation employed, as "Move part to die" or "Pick up part from table." Directly above the line, in the column headed Symbol, the symbol of the basic operation employed is recorded. If two or more basic operations are combined and performed at the same time, as transport loaded, change direction, and pre-position, the symbol for the operation which is longest from the standpoint of the time required to make it should be recorded nearest to the line, and the symbols of the other operations should be placed above. In other words, the symbol for the limiting operation is always closest to the line which represents its termination.

The number of the class of motion used is recorded in the column headed Motion Class. The number 1 is used to represent a first-class or finger motion; 2, a wrist motion; 3, a forearm motion of any type; 4, a shoulder motion; and 5, any motion where bodily movement is involved. The blocking in of the columns representing the motion class used may be done at this point, but it is usually easier to postpone this until the balance of the film has been analyzed and charted. An operator process chart at the end of charting the first two basic operations performed by the left hand will appear as shown by Fig. 79.

The remaining operations are charted in the same manner. If the cycle is short, all of the operations performed by one hand and arm may be charted before those for the other hand and arm

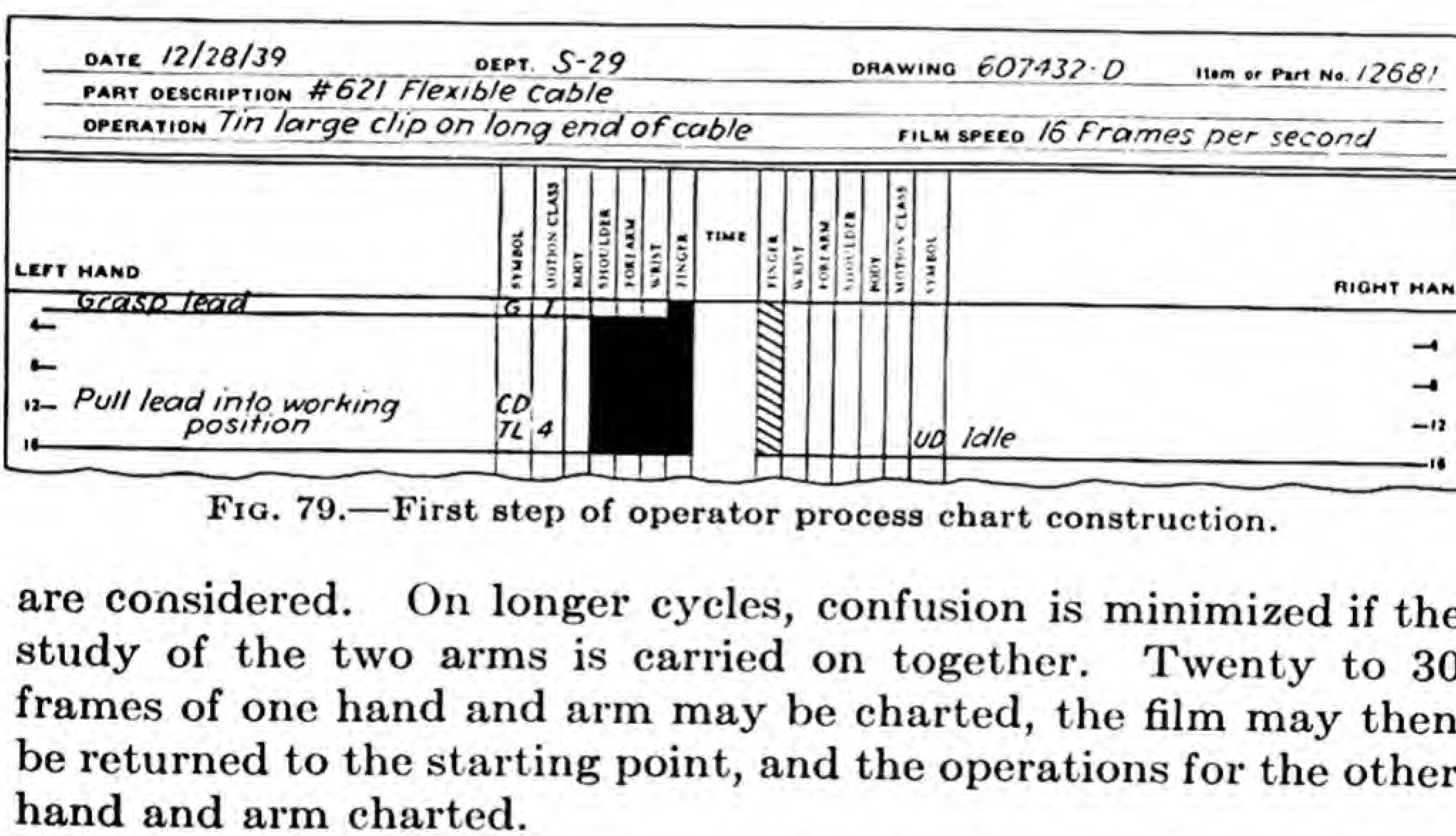


FIG. 79.—First step of operator process chart construction.

are considered. On longer cycles, confusion is minimized if the study of the two arms is carried on together. Twenty to 30 frames of one hand and arm may be charted, the film may then be returned to the starting point, and the operations for the other hand and arm charted.

If more than one operator process chart form is required for a given operation, the sheets should each be completely identified and carefully numbered in the space provided at the lower right-hand corner of the form.

When the operation has been completely charted, the chart is finished by blocking in the motion type columns. The ineffective operations are distinguished from the effective operations by color, or if the chart is to be reproduced in monochrome, by distinguishing cross hatching. Where color is used, the basic divisions of accomplishment of hold, pre-position, position, search, select, plan, avoidable delay, unavoidable delay, and balancing delay should be blocked in, in red. Thus, the points at which the

greatest possibility for improvement exist will show up at once. As the final step, the time scale should be inserted at the center of the chart as explained above. The completed operator process

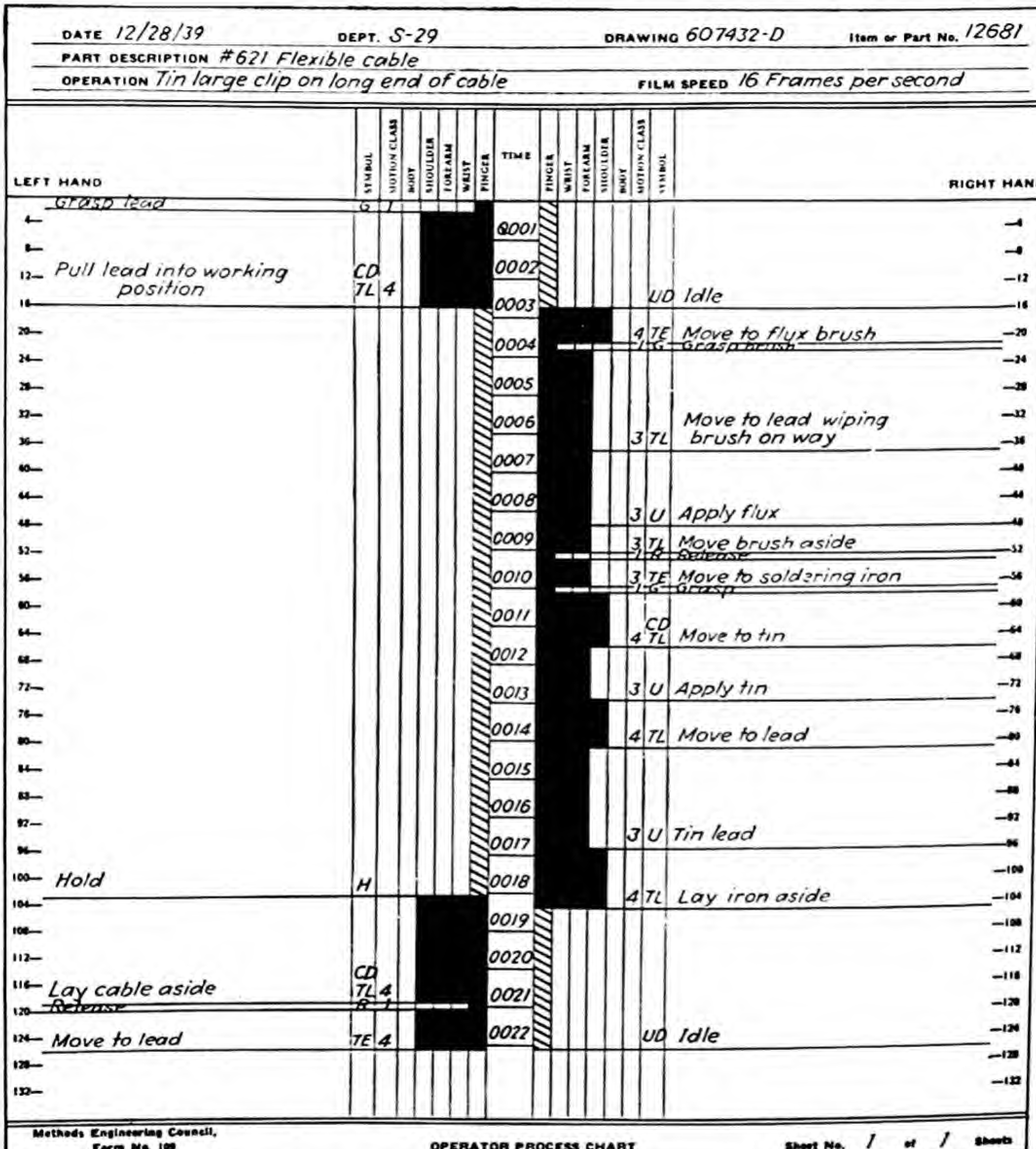


FIG. 80.—Completed operator process chart.

chart will then be similar to the one shown by Fig. 80. It may be hand-lettered, or typewritten for greater neatness.

Review of Results of Film Analysis.—The completed operator process chart should be subjected to careful study. The chart is

not an end in itself but is merely a means to an end. The red sections of the chart should first be considered. If they can be eliminated, the method will be improved. Lengthy hold or unavoidable delay operations offer particularly good possibilities for improving, and lengthy positionings which film analysis brings out to an often surprising extent can usually be reduced by proper tool and fixture design. The black sections of the chart should receive equally careful study. Transport loaded, for example, is not classed as an ineffective operation, but poor workplace layout may make it unduly long. Each basic operation of the chart should be approached with the questioning attitude and subjected to detailed scrutiny. In general, the type of reasoning described in the last section of Chap. VIII should be applied throughout.

In all probability, if the operation has never been subjected to detailed motion study before, a number of possibilities for improvement will be uncovered as the result of this analysis. As many of them as possible should be put into effect, and the operator should be instructed in the new method. The study is not necessarily completed at this point, however. The new method offers a good starting-point for still further improvement, and if the importance of the operation justifies it, the new method may be photographed and in turn analyzed. On highly repetitive work, this procedure can often be repeated several times with worth-while results. Eventually, however, the law of diminishing returns begins to operate, and it will prove more fruitful to go on to the study of another job rather than to seek still further refinements on one which has already been materially improved.

Motion-picture Film Loops.—The frame-by-frame analysis procedure gives a detailed understanding of the exact method by which an operation is done. It reveals not only the basic operations that are employed, but also the time consumed by each motion made. In the way of thoroughness, it leaves little to be desired, and the mere act of making several analyses of this type gives one an understanding of motions and motion times that it is impossible to get in any other manner. At the same time, the procedure takes considerable time, and for this reason the time-study man—after he has learned what frame-by-frame film analysis can teach him—usually employs more quickly applied methods wherever he can.

Some operations lend themselves to study by direct observation of the operation itself. Even better results, however, are obtained by studying a motion picture of the operation as it is projected on the screen. It may be studied away from the distraction of the shop, and since it is usually projected at greater than life size, it is easier to see exactly what is transpiring. In this connection, film loops are very useful. A continuous loop is made by joining the two ends of a strip of film together. The film is taken or cut so that the beginning and the end of the film strip show the same point in the cycle. Thus, when the ends of the film are cemented together and the film is run through a projector, the effect of continuous operation is obtained. The film loop may be placed on a continuous projection attachment such as that shown by Fig. 73, and it will then run continuously without further care. The analyst is thus free to devote all of his attention to his analysis of the operation.

In doing this, the analyst will find his experience in frame-by-frame analysis invaluable to him. He will be able to recognize the basic operations which are being employed and the classes of motions used. His previous experience will enable him to estimate the time consumed by each basic operation with reasonable accuracy. If any point of the operation is not clear, he can slow down the projector or even stop the projector motor and run the film through, a frame at a time, with the hand crank. The chart shown by Fig. 41 is typical of the kind of operator process chart made during an analysis of this kind, being a simplification of the charts shown above. It shows the basic operations performed by each hand and arm in their relation to each other.

A motion study made in this manner is usually sufficient to bring out many possibilities for improvement on an operation which has not been previously studied. Therefore, it may be employed to advantage by the experienced time-study man during the first stages of his study. When the method has been improved to the point where no further opportunities for betterment are recognized by studying a film loop, the detailed frame-by-frame analysis procedure may be applied if desired. On all but the most active jobs, however, the additional improvements which might be made over those obtained by an experienced time-study man studying film loops are likely to be too small to justify the additional study time required.

CHAPTER XII

STANDARDIZING THE JOB

Analysis and standardization are very closely connected. Every part of a job is first carefully considered, and the pros and cons of each proposed change are duly weighed. Then, when the final decisions are reached, the job is standardized accordingly. Analysis involves thinking of the changes; standardization involves making them.

Generally speaking, standardization is applied to a broader field than is analysis. During analysis, one particular operation is considered. In standardizing, operations as a class are considered and attempts made to standardize those which are similar. Standardization aims not only to make operations alike for any part on a given machine but also to make operations alike for any part on any similar machine anywhere in the plant.

The advantages of standardizing and specializing have been recognized in almost every industry. Few will try to belittle what has been accomplished by standardization in industrial plants where a single product is manufactured. Many, however, believe that this is the only type of plant to which the principles of standardization may be applied. It is true that a single-product plant lends itself more readily to standardization than does the plant manufacturing a variety of products in small quantities. But standardization should not be thus restricted, for there is proportionately as much to be accomplished in the latter case as there is in the former.

Manufacturing Aspects of Standardization.—The importance of standardization cannot be overstated. It brings about reduction of costs and of overhead expense in many ways, both direct and indirect. It changes the job shop which is trying to do everything that comes along and doing nothing well to the specialized shop which first determines what it shall make and then concentrates all of the facilities of the organization on the designing, the manufacturing, and the marketing of the output in the best and most economical way.

In manufacturing, standardization makes possible many things which could not otherwise be done. In the first place, it has cut down the number of designs that go from the engineering department into the shop. This means that it is possible to have longer runs for a given operation with fewer set-ups. The number of drawings and the amount of manufacturing information is reduced. With only a comparatively few drawings, the men using them soon become familiar with them and do not need to spend so much time ascertaining what must be done to finish the operation according to specifications. Often, merely a glance at the drawing title and at the dimensions is enough to tell the operator just what he must do.

When an operation is to be performed on a large quantity of parts it is possible to design special tools, jigs, and fixtures, and thus effect a saving in time which would not be possible were the quantities small and general purpose tools used. Then further standardizing and simplifying of these parts will permit a reduction in the number of tools, jigs, and fixtures themselves.

Where materials are simplified into a few classes and sizes, the stores carried on hand will be greatly reduced. Part of the money tied up in raw materials will be released for more profitable purposes. Not only will the storerooms be smaller and the number of men needed to run them be fewer, but also there will more often be material on hand when it is needed. The delays which were formerly caused by the exhaustion of the store of some special, hard-to-obtain material by an unexpectedly large order will be minimized. This is true also of raw castings and supply material.

The effect of standardization on the worker is very marked. The workman will become familiar with his job more quickly if the job is more nearly the same from day to day. He works with the same materials constantly, and he soon learns how to get the most out of his machine by using the maximum feeds and speeds. When a standard method of procedure has been established and is followed, the operator becomes highly skilled in using this procedure through constant repetition of the same motions. He becomes an expert and, as an expert, will produce more work of a higher quality with less waste, breakage, and lost time than a man working under non-standard conditions.

Supervision is greatly simplified where methods, equipment, and design are standard. One foreman can handle more men and

will not have to bother with details as he would were he constantly studying new jobs and instructing new workers. Not having this to do, he is able to concentrate on the established work of his department and can devote his time to planning better and cheaper methods for doing it. He is freer to study his men so that he may place them on the jobs for which they are best fitted.

Paper routine is reduced to a large extent by standardization. Record files are smaller, cost systems simpler, and timekeeping easier. The non-productive clerical force is smallest where all work is most nearly standard.

The inspection force is also cut down. The inspectors become familiar with the product and know just where to look for defects. This minimizes the possibility of poor work passing unnoticed. The tools of inspection, such as scales, gages, and levels, may, like the tools of production, be fewer in number and better suited to the purpose.

All of these things have the tendency to reduce costs and overhead expense. Non-productive set-ups are minimized, thus allowing the same number of machines to turn out more product or a lesser number of machines to turn out the same product. Lost time, unproductive effort, and idle machinery are greatly reduced. A better quality of product will be turned out at a lower cost of manufacture, and this product will be placed in a more favorable position in the field of competition.

Design.—The point at which to start when considering standardization is at the point where the line to be standardized is born. This is in the engineering department where the designs are first made.

Engineers, like everyone else, wish to be original and want to create something new. This tendency, while laudable in the field of research, must be somewhat suppressed in the field of minor design after the fundamental features to be incorporated in the product have been fully developed. This minor design involves the designing of various sizes, capacities, and the like, for a standard type of product. In designing several of these, the engineer is likely to make minor changes in each size part for no other reason than that he does not want anyone to believe him incapable of working out things for himself. He does not wish to appear to be copying some other engineer's work.

For instance, a cover for a certain class of tanks is to be held down by swivel thumbscrews tightened against lugs. These

covers are used merely to protect the contents of the tank from dirt, dust, and foreign matter of all kinds and do not have to be absolutely tight as they might were they used on tanks under pressure. In designing the cover for 20-, 30-, and 50-gallon tanks, the engineer may call for two, four, and six lugs, respectively. Here, two lugs would be enough to hold the cover in place on any of these tanks. The desire to be different is all that has led the engineer to specify the different numbers. In all probability, he did not realize the expense involved in machining the extra lugs on the cover and in furnishing and attaching the extra swivel thumbscrews to the tank.

Again, a rocker arm shaft may be required for two different types of magnetic contactors. Although the types are different, the purpose of the shaft is the same in either case. Here, if the design be standardized so that the same shaft may be used in either contactor, the same set-ups, tools, and jigs may be used, and the number of shafts carried in the stockroom will be reduced.

Materials.—The physical properties of materials to be used are generally determined by the conditions under which the part is to operate, but often there is a choice to be had among different grades of similar materials. Quite often, the advantage of one grade over another is purely imaginary. In many instances, it is hard to see where the use of one grade in preference to another makes any appreciable difference in the finished part, and the grade selected is often chosen for some minor reason which the advantages of standardization will more than offset. Unless the desirability of standardization be kept in mind during the selection of new materials, there will soon accumulate a large and varied assortment of materials. This leads to waste, since short ends and materials used in making a line which has been discontinued cannot readily be used up. It is necessary to maintain large stocks of raw material, and there is the danger of the supply of some special material becoming exhausted when it is most needed.

The time-study man should not overlook raw materials in his consideration of standardization; rather should he lend every assistance towards reducing the number of kinds and sizes of material used. He may find that a certain part is made from a punching and that another, only slightly different, is made from a casting. He should bring this to the attention of the design engineer and should aid him in determining which form is best

to use as a standard. Wrong applications and unnecessary variations in materials are found quite frequently, and the time-study man should make suggestions to correct such conditions whenever he finds them.

Machine Tools.—In factories where a single product is manufactured, there will be one or more machines used for a single operation. These will have a special set-up, special tools, and equipment made for a single purpose. There will be as many of these set-ups as there are operations. When a time-study man has a condition of this kind to deal with, his work will be comparatively easy; where the work is more of a jobbing nature, it is a different proposition. In the first case, when the time value is established for an operation, the whole group of machines employed on that operation is taken care of, until some change is made and it is only a matter of time before the time-study man has set time values covering every operation performed in manufacturing the product. In the second case, the time-study man must first collect sufficient data to cover every condition that might arise, and then he must repeatedly apply his data to every new job that comes along. The time-study man should, in the latter instance, try to get his conditions standardized as much as possible. He should have as his ideal the shop that is manufacturing a single product even though he knows that he can never reach that goal. He should realize that, just because the product is varied, it is not necessary to have the same number of variations in tools and equipment. At the same time, he should also keep in mind the desirability of special labor-saving conveniences for individual jobs and machines, but that these conveniences should be the same for all like conditions.

There is usually a best way for doing anything, and there is usually a certain make of machine that has advantages over all other makes of similar machines for doing a certain job. This machine may or may not be available, but there will be, among those that are available, one type that will be better than the others. It is not uncommon to see three or four different makes of machines used on the same class of work, and sometimes it is impracticable to control the flow of individual jobs so that they will be performed on the same machine every time they appear in the shop. This condition makes it necessary to determine a time allowance for each machine on which the job may be done, even though this may not be entirely satisfactory.

A good example of this occurred in a machine shop where three radial drill presses were used. On two of these machines, the speed in revolutions per minute ranged from 17 to 240 in seven steps and the feed per revolution from 0.0066 to 0.011 inch. On the other machine, the speed in revolutions per minute ranged from 44 to 474 in 22 steps and the feed per revolution from 0.007 to 0.031 inch. The advantage that the third machine had over the other two is obvious, and since it was impossible to control the flow of work to the individual machines of the group, the difficulties encountered in establishing time values may be appreciated. It was found that the third machine did approximately 35 per cent more work than the other two, and the problem was solved in this case by replacing the first two machines with one of the third type. The two that were taken out were used on other work. Of course, it is not always practicable to do this as the saving effected may not justify the expense.

Another interesting case of non-standard equipment was found in a shop which manufactured electric motor field coils. A group of semiautomatic winding machines was used for winding these coils. The work was studied, and time values were established. One of the operators consistently turned out about 30 per cent more work than any of the others. At first, the reasons for this were not understood. The operators all appeared to be working steadily, and approximately 90 per cent of the time required to wind a coil was machine time and only 10 per cent was handling time. A thorough investigation was made by the time-study man, and it developed that one of the machines had a larger driving pulley than the others. This accounted for the difference. A check was made to determine whether the product of the fast machine was satisfactory and also to ascertain how the machine was standing up. When it was found that everything was all right, it was recommended that all the machines be equipped with larger pulleys. This was done with a resultant increase in output of about 30 per cent and a proportionate reduction in cost.

The time-study man should always be on the lookout for similar conditions and should try to keep the speeds and feeds of like machine tools as nearly standard as practicable. By doing this there will be more production, and the workers will be better satisfied, since none will have any advantage over the others.

Small Tools.—The same thing that is true of machines and all power-driven tools is true of small tools, that is, cutting and hand tools, jigs, and fixtures. The same advantages should be supplied to each operator doing similar work.

It will not be attempted to treat even briefly the subject of cutting tools and of speeds and feeds, as space does not permit. In general, however, tools should be ground in the tool room by men who are experts to insure the proper shapes and angles for the class of work to be performed. One operator should not be permitted to drive screws with a plain screwdriver while another uses an automatic type. Whenever automatic tools can be used to advantage, they should be supplied and their application standardized. Jigs and fixtures should be standardized to eliminate variations in time on the same or similar operations.

Equipment.—All equipment must first be suitable for the work to be done by it. In many cases, it will be found that several different types or makes will perform the work equally well. When new equipment is being purchased, similar equipment used in other parts of the shop should be examined and an effort made to choose the new in conformity to the old. For instance, when considering the installation of a new line shaft, the hangers, bearings, and shaft sizes used in the rest of the shop should be ascertained. If the designer has determined that the new shaft must be at least $3\frac{1}{8}$ inches in diameter and it is found that $3\frac{1}{4}$-inch, but no $3\frac{1}{8}$-inch, shafting is used elsewhere, it will probably be profitable to install a $3\frac{1}{4}$-inch line shaft. Then it will not be necessary to carry spare shafting, bearings, couplings, and pulleys $3\frac{1}{8}$ inches in diameter. In case of breakdown, spare parts may be drawn from the $3\frac{1}{4}$-inch supply already on hand.

In a foundry where patterns may range in area from 1 square inch up to several square feet, standardization of equipment is very important. If a special flask were used for each size of pattern, there would be no end of storage difficulties, delays, and time spent in flask handling, to say nothing of the amount of money that would have to be invested to provide enough of each different size of flask to have on hand when needed; rather should flasks of certain standard sizes be provided to be used with patterns between certain ranges, thus greatly lessening the difficulties mentioned above.

Where electric trucks are used for material handling, it will be profitable to adopt one good make of truck as standard. Then

any driver will be able to operate any truck, and the repair men will be able to do their work more effectively, since they will be thoroughly familiar with the construction of the trucks. Charging equipment and battery units may then be standardized and the stock of repair parts kept may be small.

Relation of Standardization to Time Study.—Just as the workman becomes an expert in his work by constantly doing similar operations on the same materials, so will the time-study man become expert in his work by studying work under standardized conditions. He will know at once whether the best method of procedure is being followed on a new job, because he has previously determined the best method when studying another similar job. He will be better able to judge the effort and the skill of an operator by knowing what effort or what skill this operator or other operators should show when doing this class of work. Any man, when seeing an operation performed for the first time, will compare what is being done to what he could do himself, and if the job requires manual dexterity, he is likely to consider even the poorer operators as skilled. When he has had more experience and has seen really skilled operators work, he is able to judge more exactly what an operator is capable of doing. In this way, his judgment will improve with constant work along similar lines, and he will be able to make more intelligent analyses, determine skill and effort more exactly, and arrive at more consistent time allowances.

The time-study man will be able to play no small part in bringing about and maintaining standard conditions. He is directly responsible for standard methods of procedure. He is able, indirectly, through suggestions which his knowledge of minute details of the work and his analytical point of view enable him to make, to standardize design, equipment, tools, materials, and the like.

CHAPTER XIII

TIME-STUDY EQUIPMENT

The success of time-study work depends mostly upon the ability of the time-study man, rather than upon the tools that he uses, for the equipment requirements for making good time studies are simple and few. Yet he must have those few things and know how to use them properly in order to do satisfactory work. The principal items of equipment are:

A time-study watch.
A speed indicator.
Time-study forms.
A pencil.
An observation board.
A slide rule.

The Time-study Watch.—The watch is, of course, the most important item of time-study equipment. Various kinds of watches from the ordinary timepiece to very complex stop watches have been used or advocated by time-study authorities. The ordinary watch may be read in hours, minutes, and seconds, the latter being the shortest units of time that it will indicate. It is useful to record the time of day at the beginning and at the end of a time study, but the ordinary watch is not a practicable instrument for detailed observation, primarily because of the difficulty in reading it and because the second is not commonly used as a unit for the measurement of working time. Authorities, therefore, have generally agreed that some form of stop watch gives more satisfactory results. Three common types of stop watches are:

The split-second stop watch.
The minute-decimal stop watch.
The hour-decimal stop watch.

The Split-second Stop Watch.—The most widely known type of stop watch (see Fig. 81) is the one which is ordinarily used by timekeepers of athletic events, particularly running. The circumference of the dial is graduated into 60 divisions each of

which represents 1 second. Every fifth graduation is numbered to facilitate reading. Each space representing 1 second is in turn divided into fifths which makes it possible to read accurately to fifths of a second. The watch is started, stopped, and the hand returned to zero by pressing the stem. This type of watch is very well adapted to the kind of work for which it was designed, the accurate timing of one particular operation such as a 100-yard dash. During the preparations previous to the starting gun, the hand is held motionless at zero, and the watch is not running. At the sight of the flash from the starter's pistol, the timekeeper presses the stem of the watch, thus setting it in

FIG. 81.—Split-second stop watch.

operation. When the runner touches the tape, the stem of the watch is again pressed stopping the hand instantly and holding it where it is until the watch can be read accurately at leisure. The hand can then be returned to zero by again pressing the stem.

In time-study work, however, one elemental operation follows another immediately, and the end of one is at the same time the beginning of the next. The time required to stop the watch, read it, return the hand to zero, and start it again, although short, is sufficient to introduce appreciable errors. These errors can be eliminated by using the continuous method of reading the watch, but then the closeness of the graduations and the fact that they

are fractional make it next to impossible to read the moving hand and record the readings accurately for short operations, and would require considerable subsequent calculations.

The Minute-decimal Stop Watch.—The minute-decimal watch illustrated in Fig. 82 is more satisfactory than the split-second watch. It is similar in that a complete revolution of the hand consumes 1 minute. The dial is graduated decimally into hundredths rather than sixtieths, which makes it considerably easier to read and reduces the amount of calculation necessary to translate elapsed time into the commonly used units for expressing time values.

FIG. 82.—Minute-decimal stop watch.

The Hour-decimal Stop Watch.—The hour-decimal watch, illustrated in Fig. 83, has a number of distinct advantages over the two kinds just described, and is the type which was used in making all the detailed time studies which will be described or referred to in this book. Chief among its advantages is that it is read directly in hours, the most common unit of time measurement in industry. The length of a working day is expressed in hours; wage rates are expressed as so many cents an hour; payroll calculations are on the basis of hours worked. It is, therefore, advantageous to have time values recorded directly in hours, because of the reduction of the necessary calculations and the

elimination of one source of clerical errors. The dial is divided into 100 spaces each of which represents 0.0001 hour, thus making one revolution of the hand equivalent to 0.01 hour. Having the same number of spaces on the circumference of the dial, this watch is no more difficult to read than the minute-decimal watch; yet because the hand is running at a faster rate of speed, it tends toward more accurate measurement of elapsed times.

The hour-decimal watch is controlled by the button *A* and the winding stem *B* as indicated in Fig. 83. The stem controls the

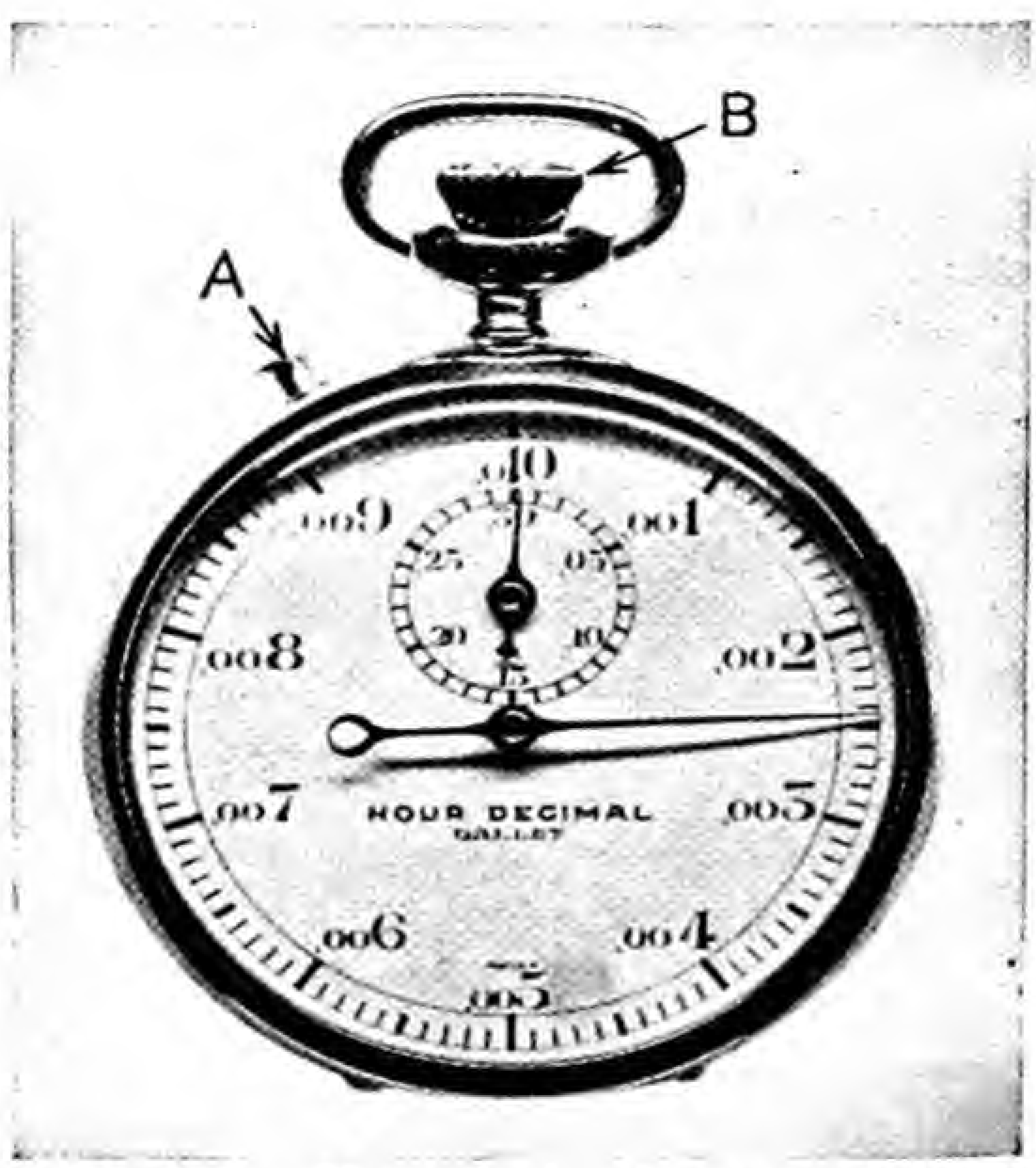


FIG. 83.—Hour-decimal stop watch.

starting and stopping of the watch and makes it possible to stop the hand at any point in a revolution and to start it again from that position. By pressing the button *A*, the hand is returned to zero, but it starts immediately upon release of the button, thereby making it unnecessary to press the button again to start the hand, as in the case of the split-second watch. If it is desired to hold the hand to zero, this may be done by holding the button down. The position of the large hand on the dial indicates accurately to four decimal places time in hours, and the small hand indicates hundredths of an hour directly on its dial and is controlled in synchronism with the large hand by means of the slide and stem.

When using a stop watch, there is a tendency to assume that as long as it will run, it is keeping accurate time, but this is not always true. A man will notice very quickly if his ordinary watch is not keeping accurate time, because he compares it frequently with the many other timepieces he sees. A stop watch, not being

Seconds	Decimal minutes	Decimal hours	Seconds	Decimal minutes	Decimal hours
1	0.017	0.00028	31	0.517	0.0086
2	0.033	0.00056	32	0.533	0.0089
3	0.050	0.0008	33	0.550	0.0092
4	0.067	0.0011	34	0.567	0.0094
5	0.083	0.0014	35	0.583	0.0097
6	0.100	0.0017	36	0.600	0.0100
7	0.117	0.0019	37	0.617	0.0103
8	0.133	0.0022	38	0.633	0.0106
9	0.150	0.0025	39	0.650	0.0108
10	0.167	0.0028	40	0.667	0.0111
11	0.183	0.0031	41	0.683	0.0114
12	0.200	0.0033	42	0.700	0.0117
13	0.217	0.0036	43	0.717	0.0119
14	0.233	0.0039	44	0.733	0.0122
15	0.250	0.0042	45	0.750	0.0125
16	0.267	0.0044	46	0.767	0.0128
17	0.283	0.0047	47	0.783	0.0131
18	0.300	0.0050	48	0.800	0.0133
19	0.317	0.0053	49	0.817	0.0136
20	0.333	0.0056	50	0.833	0.0139
21	0.350	0.0058	51	0.850	0.0142
22	0.367	0.0061	52	0.867	0.0144
23	0.380	0.0064	53	0.883	0.0147
24	0.400	0.0067	54	0.900	0.0150
25	0.417	0.0069	55	0.917	0.0153
26	0.433	0.0072	56	0.933	0.0156
27	0.450	0.0075	57	0.950	0.0158
28	0.467	0.0078	58	0.967	0.0161
29	0.483	0.0081	59	0.983	0.0164
30	0.500	0.0083	60	1.00	0.0167

Fig. 84.—Conversion table showing equivalents of seconds expressed in decimal minutes and decimal hours.

essentially an instrument for telling the time of day, may be running too fast or two slow and not be noticed unless it is periodically checked with a timepiece of known accuracy. The ordinary stop watch is not a high-grade mechanism and may require

trequent regulation, especially when it is considered that it does not ordinarily receive as careful treatment as a good watch. When checking the accuracy of a stop watch, the test should not be limited to 1 or 2 minutes but should extend over at least a half hour.

Conversion Tables.—For the sake of clearness and uniformity, all numerical examples given in this book are expressed in decimal hours. If it is desired to convert any time values to either decimal minutes or seconds, it may be done readily by reference to the conversion tables shown in Figs. 84 and 85. Accurate conversions may be made by means of the following formulas:

Decimal minutes	Decimal hours	Decimal minutes	Decimal hours	Decimal minutes	Decimal hours
1	0.0167	8.25	0.138	32	0.533
1.25	0.0210	8.50	0.142	33	0.550
1.50	0.0250	8.75	0.146	34	0.567
1.75	0.0290	9	0.150	35	0.583
2	0.0330	9.25	0.154	36	0.600
2.25	0.0380	9.50	0.158	37	0.617
2.50	0.0420	9.75	0.163	38	0.633
2.75	0.0460	10	0.167	39	0.650
3	0.0500	11	0.183	40	0.667
3.25	0.0540	12	0.200	41	0.683
3.50	0.0580	13	0.217	42	0.700
3.75	0.0630	14	0.233	43	0.717
4	0.0670	15	0.250	44	0.733
4.25	0.0710	16	0.267	45	0.750
4.50	0.0750	17	0.283	46	0.767
4.75	0.0790	18	0.300	47	0.783
5	0.0830	19	0.317	48	0.800
5.25	0.0880	20	0.333	49	0.817
5.50	0.0920	21	0.350	50	0.833
5.75	0.0960	22	0.367	51	0.850
6	0.100	23	0.383	52	0.867
6.25	0.104	24	0.400	53	0.883
6.50	0.108	25	0.417	54	0.900
6.75	0.113	26	0.433	55	0.917
7	0.117	27	0.450	56	0.933
7.25	0.121	28	0.467	57	0.950
7.50	0.125	29	0.483	58	0.967
7.75	0.129	30	0.500	59	0.983
8	0.133	31	0.517	60	1.000

FIG. 85.—Conversion table showing equivalents of minutes expressed in decimal hours.

$$\text{Decimal hours} \times 60 = \text{decimal minutes or } \frac{\text{decimal minutes}}{60} = \text{decimal hours.}$$

$$\text{Decimal hours} \times 3600 = \text{seconds or } \frac{\text{seconds}}{3600} = \text{decimal hours.}$$

Other Devices.—Numerous mechanical and electrical devices to aid in reading and recording observations have been invented and placed on the market. When competently handled, they may perhaps give individual time readings that are somewhat more accurate than those obtainable with a stop watch. When the continuous observation method described in the next chapter is used, however, inaccuracies in watch readings—which should be relatively few if the observer is competent—are averaged out when the study is worked up. It is unlikely, therefore, that the final time value arrived at from a study taken with a time-study machine and one from a stop-watch study will vary appreciably if the same method of working up the data is used. Hence, the less expensive and less cumbersome stop watch is entirely satisfactory for the time-study work undertaken for rate-setting purposes and is widely used.

Where extremely accurate time data is required on individual elements, the use of some form of time-study machine may be justified. Complete directions for use are furnished by the makers of such machines. It should also be noted that equally accurate elemental time data can be secured from the frame-by-frame analysis of a motion picture of the operation as described in Chap. XI.

The Speed Indicator.—This item of time-study equipment is not required for every time study that is made, but it is very useful when studying machining operations where cutting speeds are an important factor. Even though nearly every modern machine tool has attached to it a table showing spindle, tool, or table speeds for the various gear and belt combinations, experience has shown that these charts should not be relied upon entirely, because the purchaser of the machine tool does not always install it strictly according to the manufacturer's recommendations. Variation in line-shaft speed or in the diameter of the line-shaft pulley will naturally result in actual machine speeds that do not conform to those calculated by the manufacturer of the machine tool. It is, therefore, advisable actually to measure machine speeds when the study is being made.

There are various styles and designs of revolution and speed counters, which will fulfill a time-study man's requirements. The type illustrated with attachments in Fig. 86 has been found entirely satisfactory for ordinary purposes. For determining spindle or shaft speeds, it may be used without attachments if there is a center hole in the end of the shaft. The reading on the dial shows revolutions for the time the counter was held against the end of the shaft. It is then a simple matter to calculate the revolutions per minute. Attachment *A* is used when it is desired to measure surface speeds. It may be used to determine speed of translation or of rotation merely by holding the small rubber wheel against the moving surface so that the axis

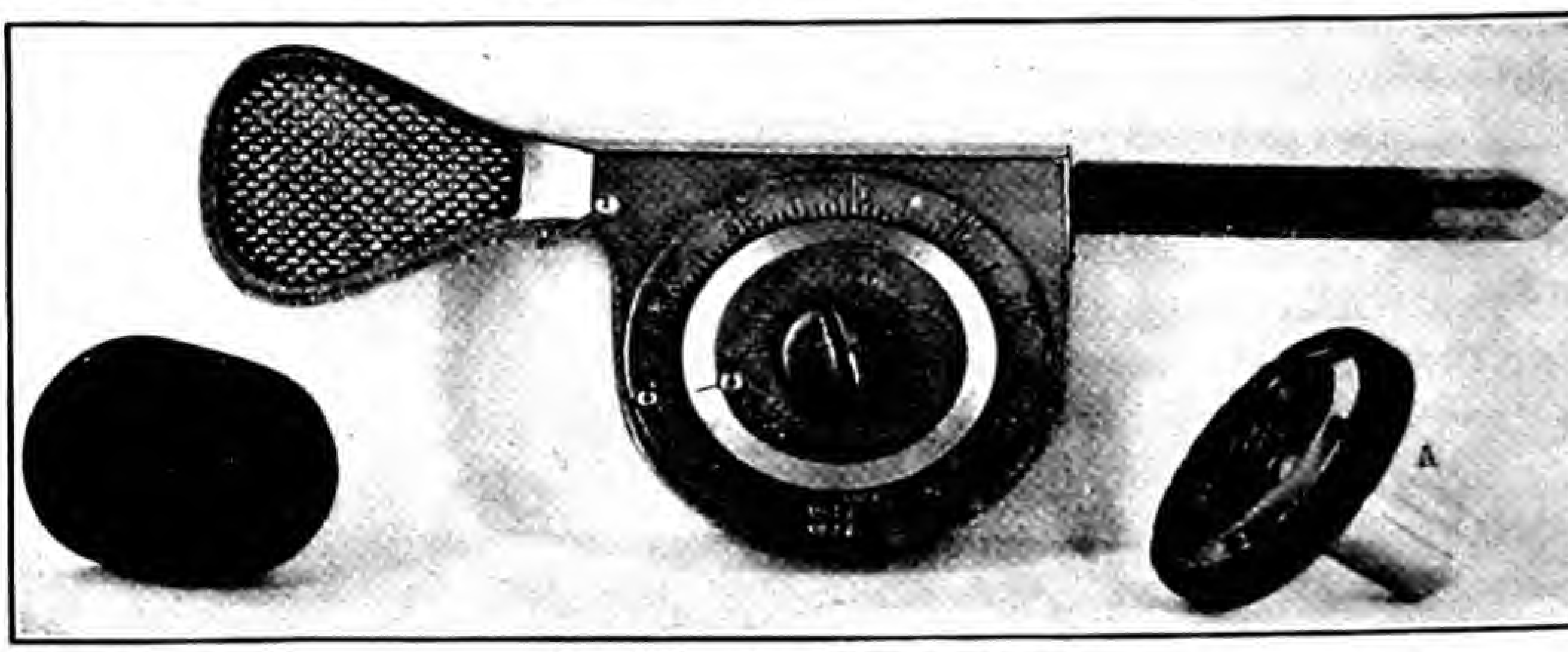


FIG. 86.—Speed indicator.

of the wheel is in a plane parallel with and perpendicular to the direction of motion. Since the diameter or circumference of the small wheel and the number of revolutions for a measured period of time are known, the speed in feet per minute can readily be calculated.

Time-study Form.—The time-study form which is illustrated by Figs. 87 and 88 is the outgrowth of a number of years of development, and it has been used and found satisfactory in practically every type of industry and on all manner of operations in both the factory and the office. The form is designed to provide for the recording of the maximum amount of data in the minimum space. It is 8½ by 11 inches in size, which makes it convenient for filing, and it contains provision for complete identifying information and for summarizing the recorded data.

This time-study form provides adequately for the recording of all identifying information and facts pertinent to the job studied.

It plainly indicates what information is neccesary in order to avoid the danger of omitting any essential facts and identifying numbers or descriptions. Space is provided for a sketch of the part or workplace layout, which aids materially in visualizing the job.

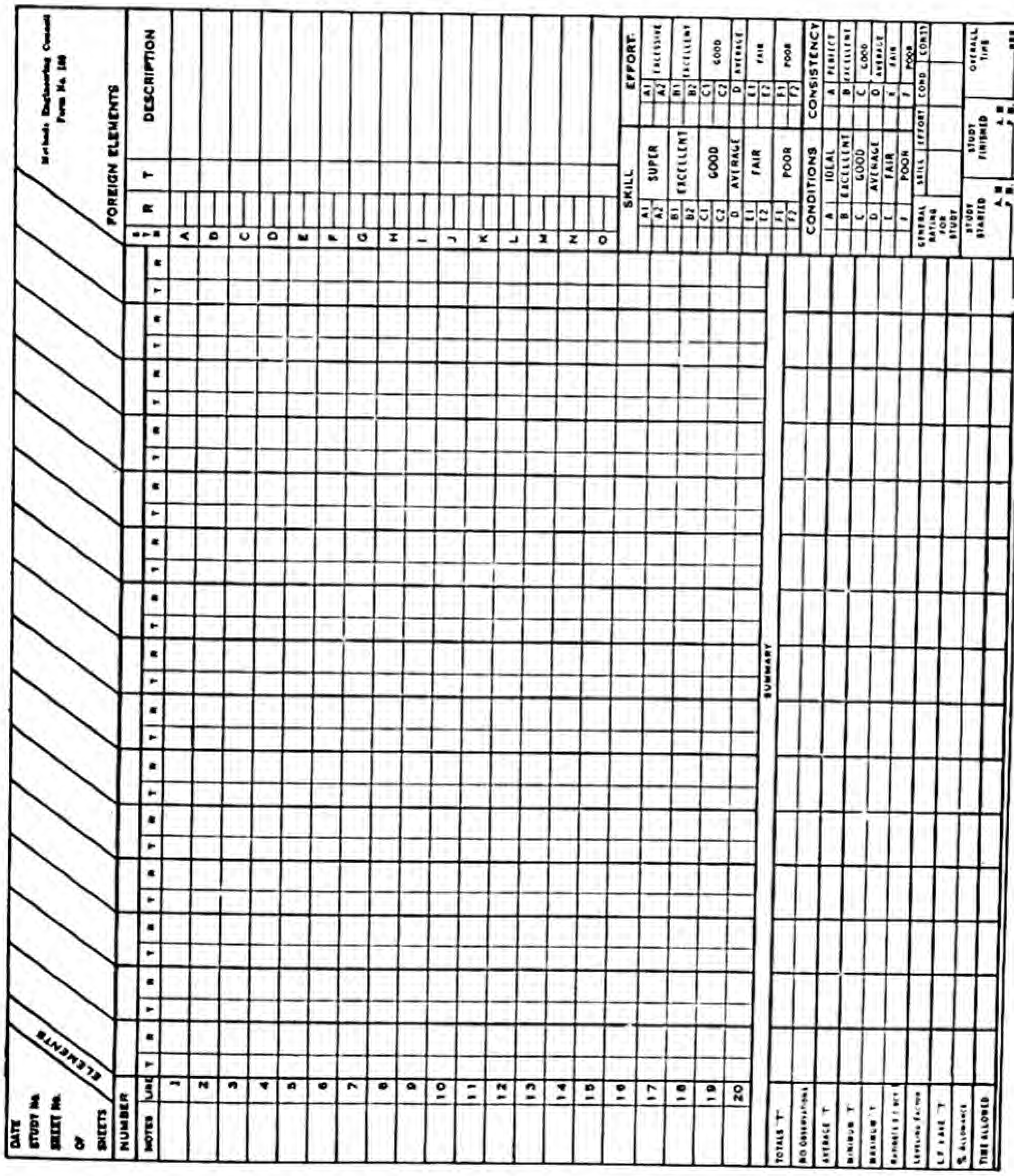


FIG. 87.—Face of time-study form.

A time-study form can be designed so that the successive watch readings are recorded in horizontal lines or in vertical columns. The horizontal line arrangement facilitates summarizing the data, and, therefore, it is used on the form shown by Figs. 87 and 88 and throughout the book. Figure 104 shows how the

model time study presently to be described would appear on a form of the vertical column type.

The form illustrated by Figs. 87 and 88 was designed for the continuous method of reading the watch, although the snap-back method can be used if desired. The oblique spaces along the top

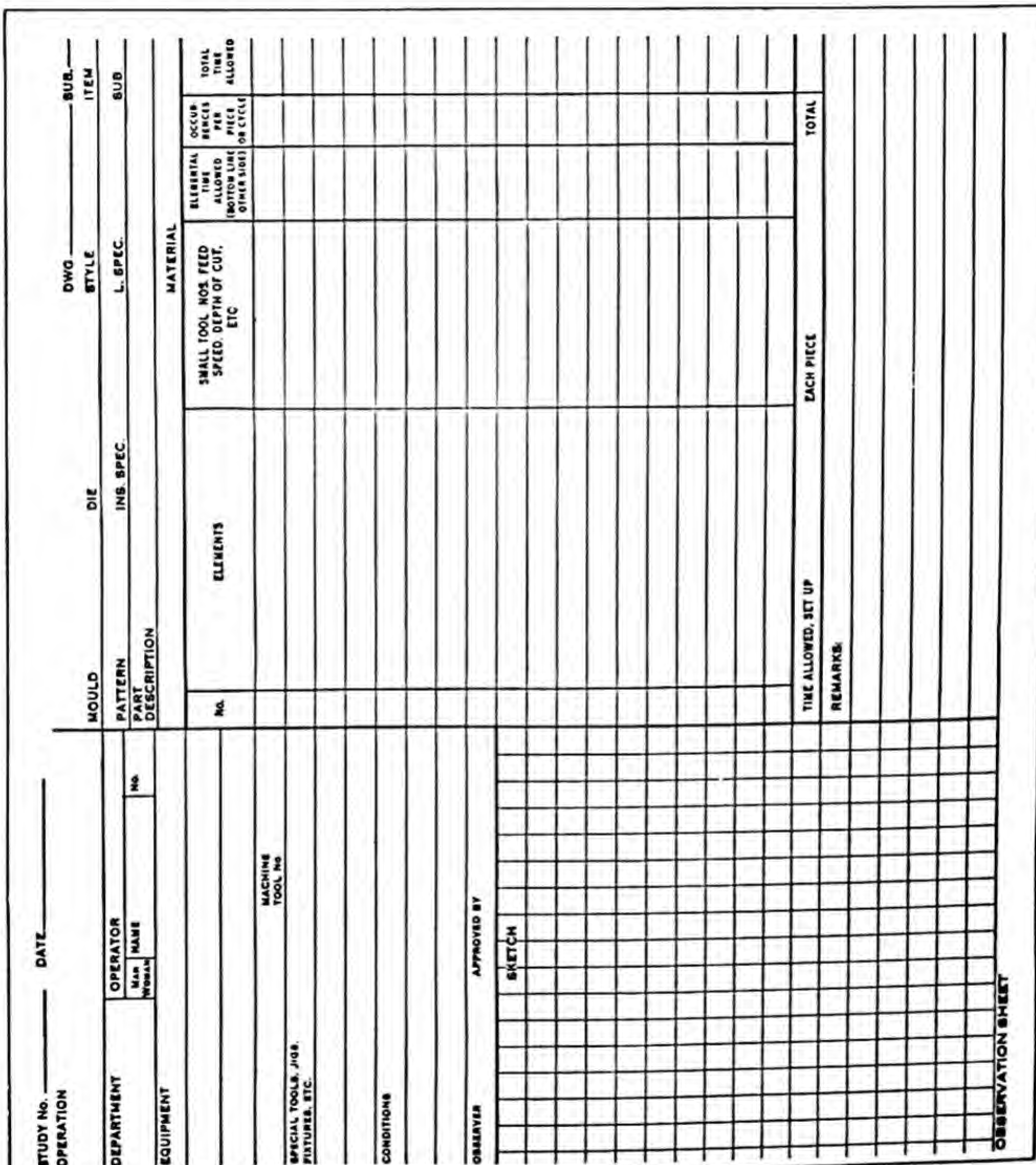


FIG. 88.—Back of time-study form.

of the sheet provide for descriptions of the elements, and the first line immediately below is for numerical symbols which are convenient reference identifications. Each column as marked by the heavier ruling is subdivided into two narrower ones. The one on the right, headed *R*, is for the watch reading, and the other, headed *T*, is for the elapsed time. Thus, when making subtrac-

tions later, the elapsed-time figure falls conveniently and naturally between the two watch readings which determine it.

The Pencil.—Little need be said regarding this item of a time-study man's equipment except that, for the sake of neatness, the pencil should be kept sharply pointed and should be of sufficient hardness, say 3H or 4H, to prevent smearing or obliteration, because a time study is sometimes subjected to considerable handling and reference. As an aid toward keeping the point of the pencil in good condition, a small piece of emery

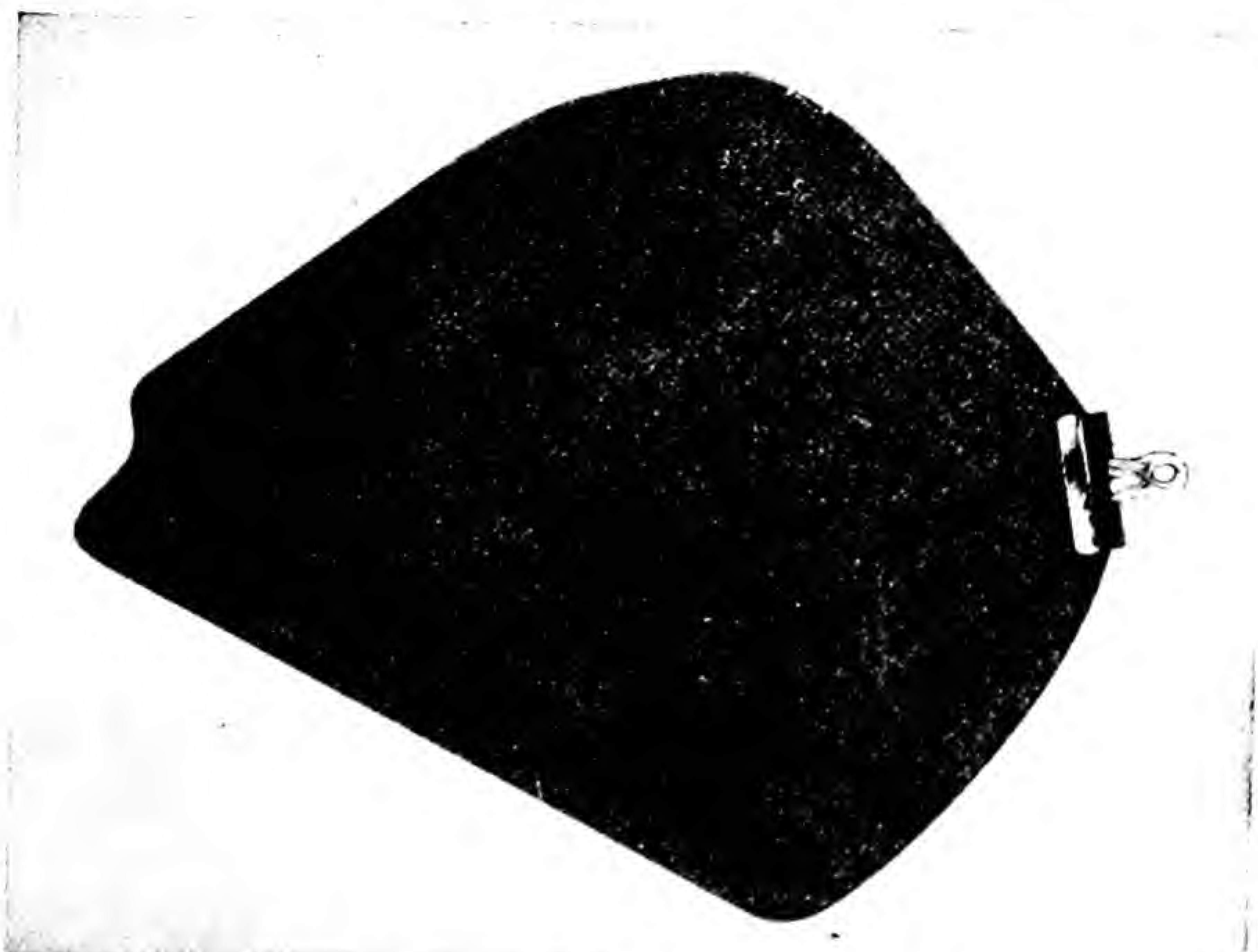


FIG. 89.—Time-study observation board.

cloth or sandpaper may be fastened on the observation board. A few strokes over this abrasive when time permits during the study will keep the pencil point well sharpened. The pencil should also carry an eraser.

The Observation Board.—The time-study man is generally obliged to stand up and often to move about while making his observations. When it is remembered further that he must concentrate his attention simultaneously upon the movements of the operator and the hand of his watch while holding his time-study forms and his watch in one hand and busily writing down the watch reading with the other hand, it will be appreciated that some device for holding firmly the watch and the forms will

be of considerable assistance. A thin light board similar in design to the one illustrated in Fig. 89 has been found to be quite satisfactory for this purpose. A device for holding the watch is attached to the top of the board, and a strong spring clip for holding the time-study sheets is placed in the upper right-hand corner. By standing in the proper position, the time-study man can bring directly into his field of vision the three things demanding his attention, namely, the operator, the watch, and the time-

Fig. 90.—Manner of holding the observation board while making a time study.

study sheet. Since the sheets are held by one corner only, they may be readily leafed over and allowed to hang over the edge of the board when more than one sheet is required for the study. The photograph in Fig. 90 illustrates the proper method of holding the board.

The Slide Rule.—The slide rule is, of course, not indispensable, but a time-study man will find it a very useful time-saving tool in computing time allowances, adding percentage allowances, and in constructing and applying formulas. Space will not be taken here to describe the principles and applications of the slide rule, but its use is strongly recommended.

CHAPTER XIV

OBSERVATIONS

Broadly speaking, observations include the securing and recording of all data and facts necessary to the computation of the time value, but this chapter will be confined to a discussion of only those observations which are made, and can be made, at the time and place of performance. They include breaking the job up into its elements and listing them in their proper sequence, reading the watch and recording the readings, and making a memorandum of the skill and of the effort displayed by the operator.

Position of the Observer.—The time-study man should stand in a position such that the hands of the operator are visible and so that the watch attached to the top of his board will come into this same line of vision. If conditions permit, the time-study man should stand a few feet away and in back of the operator so that he will not interfere with the operator or distract his attention. It may be necessary to move about occasionally for certain kinds of work. He should hold the time-study board firmly with his left hand and arm, in a position that will be comfortable and natural for writing. Figure 91 illustrates the proper position in which the observer should stand with respect to the operator.

The time-study man should stand up while making observations. This creates a favorable psychological effect upon most workers, especially upon those who are not accustomed to working under observation. There is a natural resentment on the part of most operators for a time-study man who settles himself comfortably in a sitting position to watch them work and to make a record of their performance. The confidence and respect of the working force are so difficult to secure at the outset when introducing time-study work that they should never be jeopardized by apparent laziness on the part of the time-study man. Furthermore, it is a recognized fact that a person is more alert when standing than when sitting. Time-study work demands alertness and concentration to a maximum degree, and this should be sufficient reason for standing while making observations.

One important exception to the above occurs when office work is being studied. In offices, the majority of the workers are usually seated. Therefore, if the observer stands, he is rather conspicuous and is likely to make the workers nervous and constantly aware of his presence. In this case, therefore, it would be better for the observer to seat himself while making his observations. In any case, his object should be to conform in his actions as

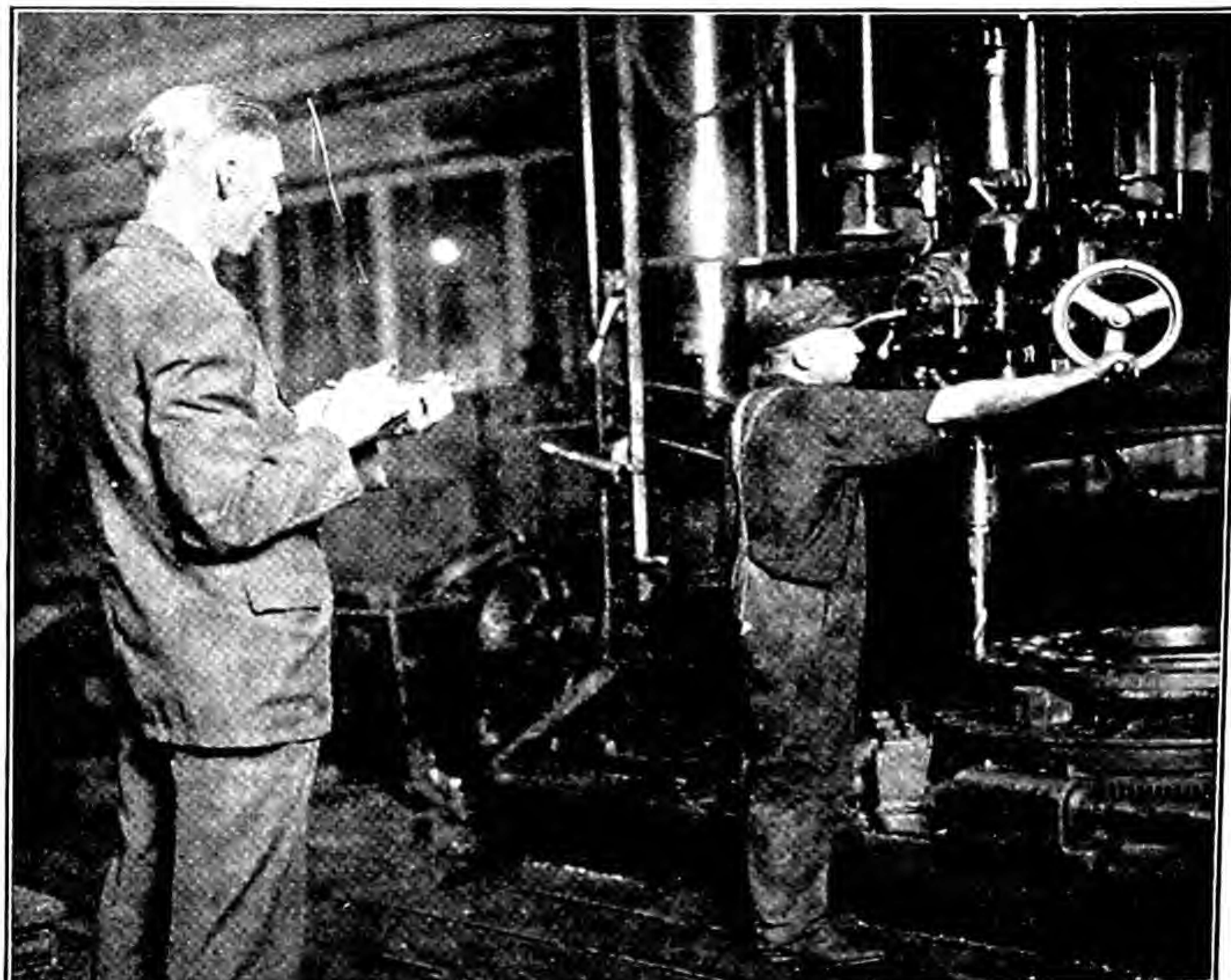


Fig. 91.—Position of the observer while taking time study.

closely as possible with those among whom he is working and to do his work in such a way that he causes a minimum of disturbance to normal conditions.

Subdividing Jobs into Elements.—As shown in Chap. VII, all physical activity, regardless of the magnitude of accomplishment, consists of the 18 basic divisions of accomplishment used in varying combinations and sequence. These basic operations, however, are of too short duration to time with a stop watch. Therefore, for time-study purposes, the operation is subdivided

into small operations called elements. These elements contain a number of basic divisions of accomplishment, but they are comparatively short and lend themselves to study. When a job is of such nature that a detailed motion study is not economically justifiable, the act of subdividing the job into its elements provides the opportunity for making a sort of rough, overall motion study which is often sufficient to detect unnecessary work.

In subdividing a job into elements, certain general principles should be followed. The first and chief one of these principles is that the basic fundamental of time study is the studying of a job by studying its elements, and the shorter these individual elements are, the better they lend themselves to close study. A job, therefore, should be divided as minutely as is consistent with accuracy in making the observations. The advantages of further subdivision are more than offset by the disadvantages of inaccurate readings. For instance, it is humanly impossible to observe and record accurately the watch readings for a dozen successive elements each of which is no longer in duration than 0.0002 hour or consuming a total elapsed time of 0.0024 hour, whereas three or four elements occurring in that same 0.0024 hour would be comparatively simple to handle with accurate results. This does not mean, however, that elements of but 0.0002 hour's duration should always be combined with others to make longer ones. One or even two very short elements, if they fall between comparatively long ones, are not difficult to observe and record, for the readings can be remembered and recorded during the next element of greater length.

Another point which should be considered when dividing a job into its elements is that there are two main classes of elements, constants and variables. A full discussion of these two classes of elements will be presented in a later part of this book under the general subject of formula construction, so it will be sufficient to say here that a constant is an element which should require no more time when it is a part of one job than when it is a part of another job performed under the same working conditions and with the same equipment. Conversely, a variable is an element the length of which will be, or may be, different when it occurs in different jobs, as influenced by the characteristics of the individual jobs, such as weight, size, length, and shape. The point to be borne in mind in connection with constants and variables is that they should be kept separated. If it is necessary to

combine short elements, the combinations should be limited to constants, if at all possible.

The steps taken in making a complete time study will be illustrated by a series of figures (Figs. 92, 97, 98, and 106) showing a

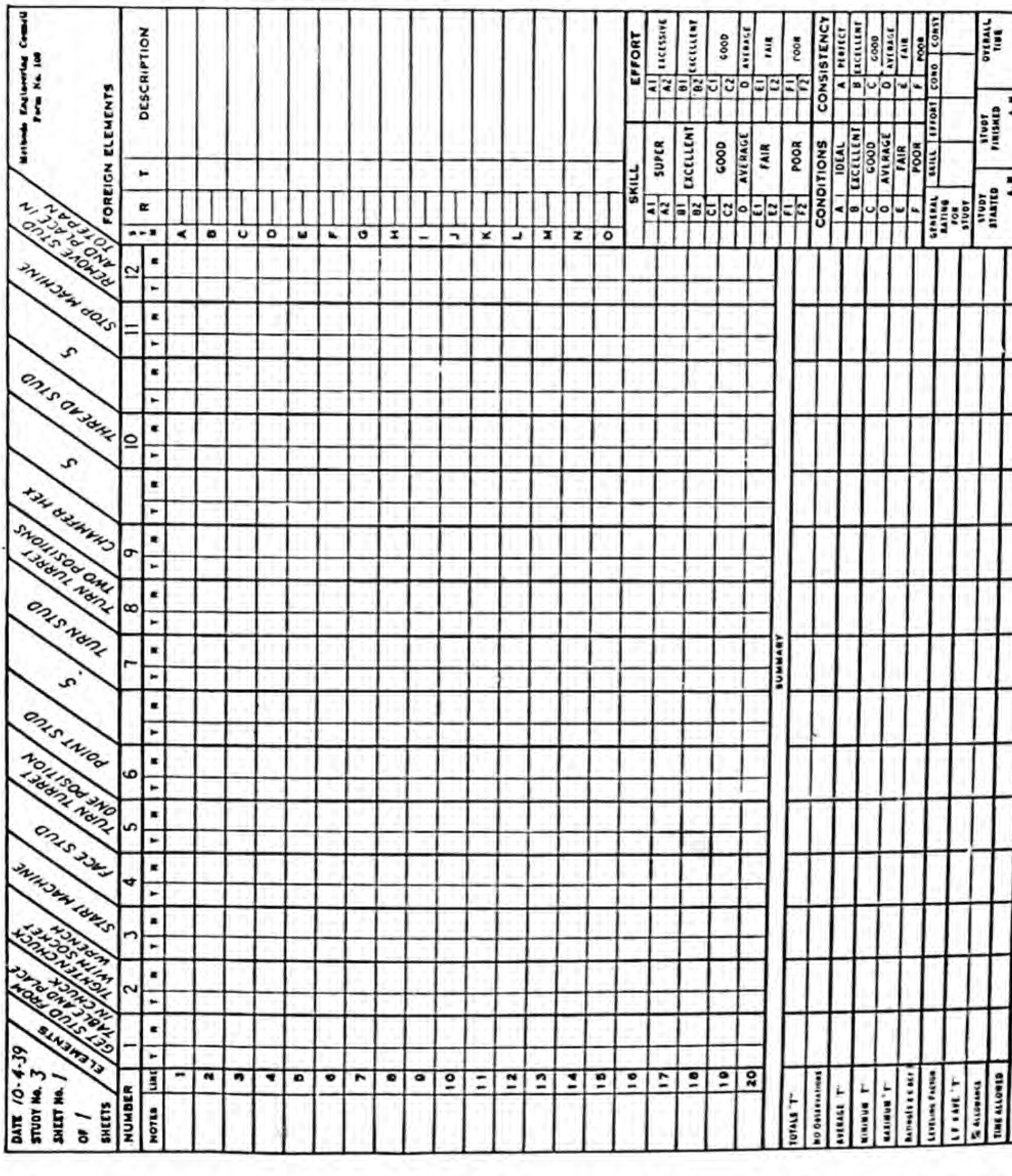


FIG. 92.—Model time study showing subdivision into elements completed.

model time study at various stages of completion. Figure 92 shows how a time study on facing, pointing, turning, and threading a copper stud will appear when the subdivision of the operation into elements has been completed.

When arranging the sequence of elements on the time-study form, it is desirable to keep the study on one sheet if feasible,

on account of the possibility of two or more sheets becoming separated, resulting in the loss of part of the data. Another advantage is that there are no pages to be turned during the observations.

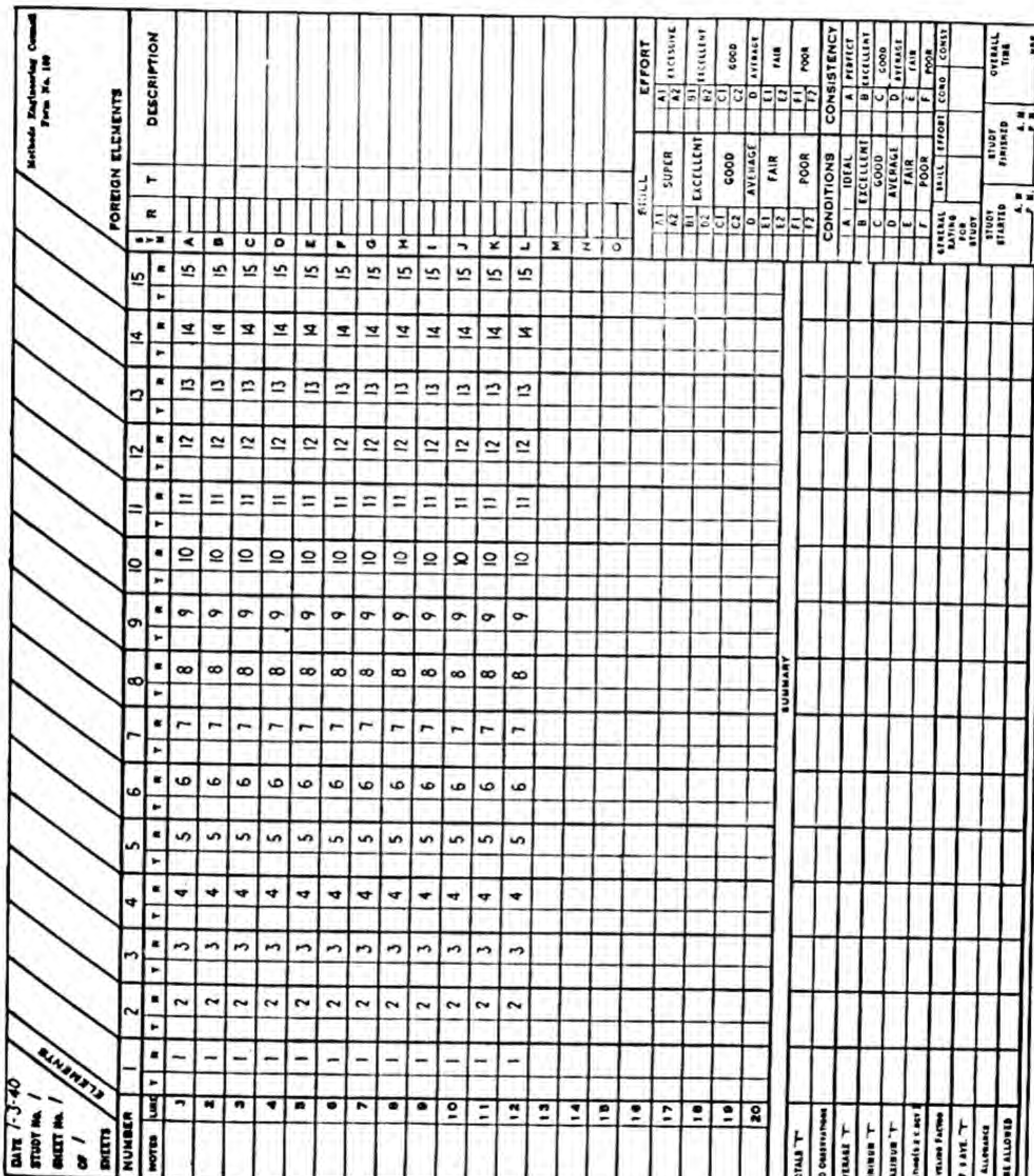


FIG. 93.—See page 187.

The time-study form illustrated in Figs. 87 and 88 was described as being of the horizontal-line type, the sequence of elements to be listed along the top of the sheet and successive readings to be recorded in horizontal lines. It does not follow, however, that only one line can be devoted to each piece studied. When the operation consists of a large number of entirely different ele-

ments, there is no alternative but to list them, one to each diagonal space at the top of the sheet, and using as many sheets as are necessary to provide for one complete cycle. Many times, however, one or more elements or series of elements are repeated a number of times in every cycle or on every piece. It is fre-

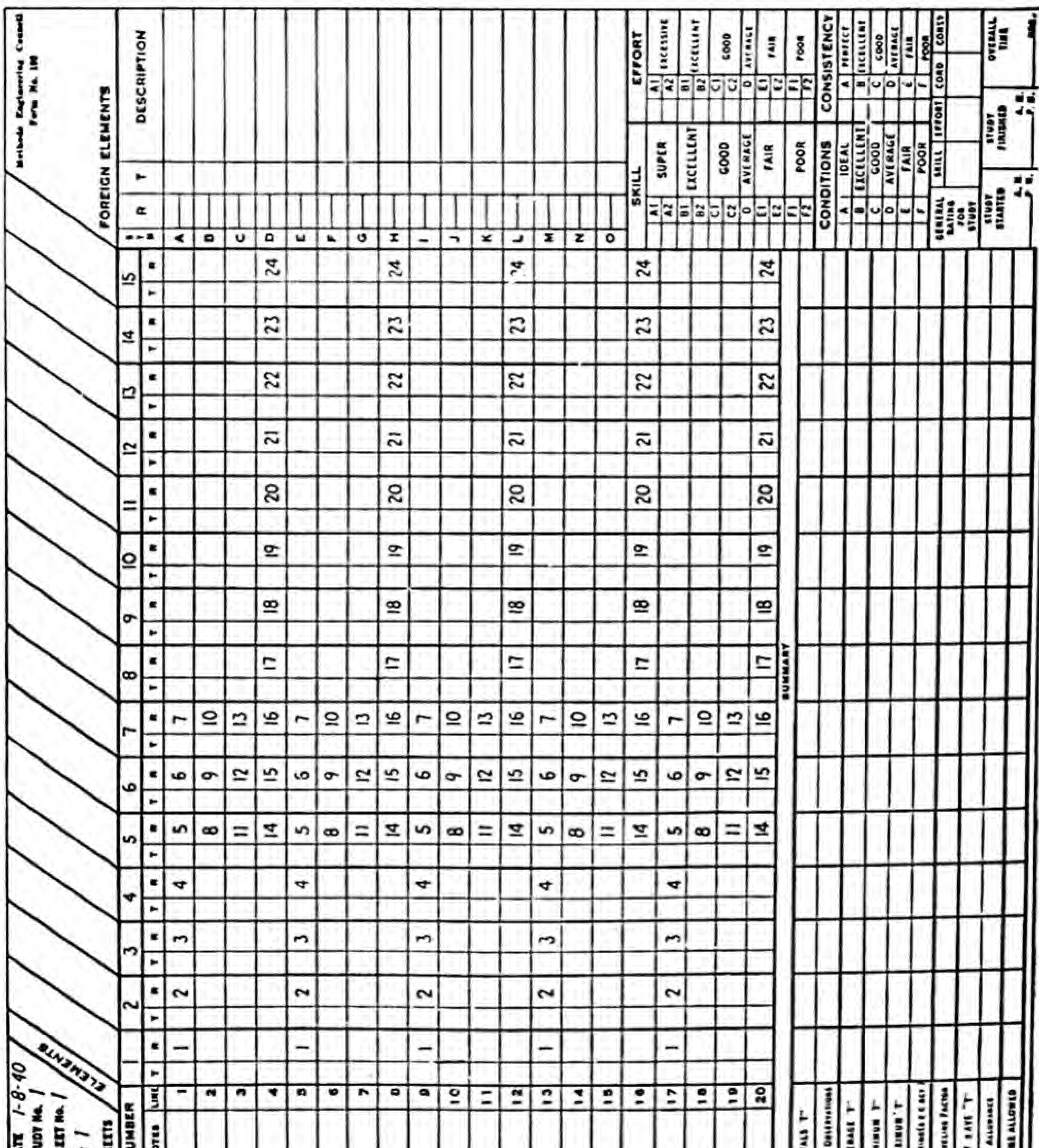


FIG. 94.—See page 188.

quently advantageous, in such cases, to record these particular elements vertically, until the last performance of the repeated elements. The elements to follow should then be contained horizontally on the same line as the last recorded reading for the repeated element. Figures 93 to 96 inclusive show different

typical arrangements of the sequence of elements and the observations on the time-study form. These examples do not represent, by any means, all of the different possible arrangements but are merely suggestive of what can be done toward recording the

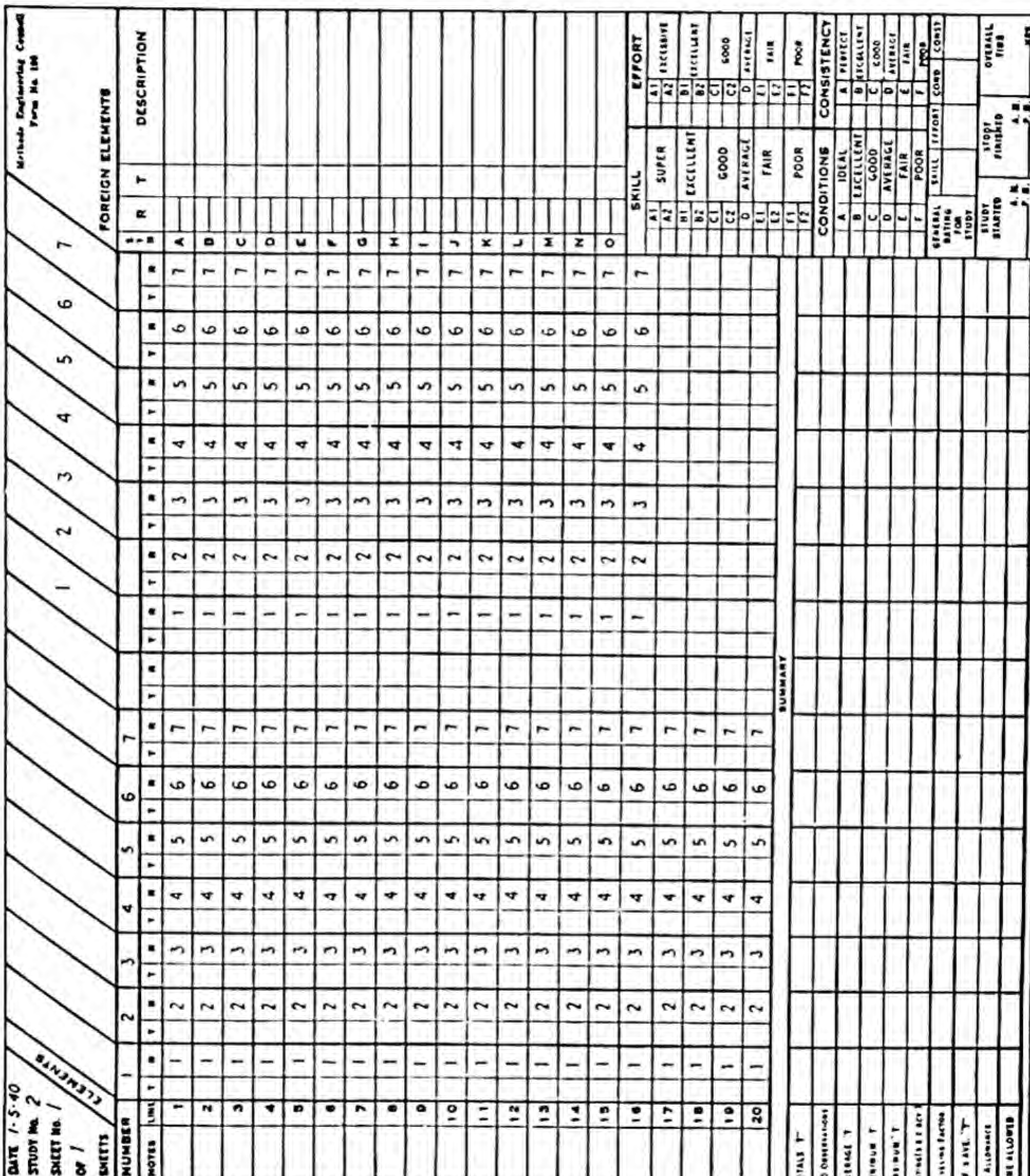
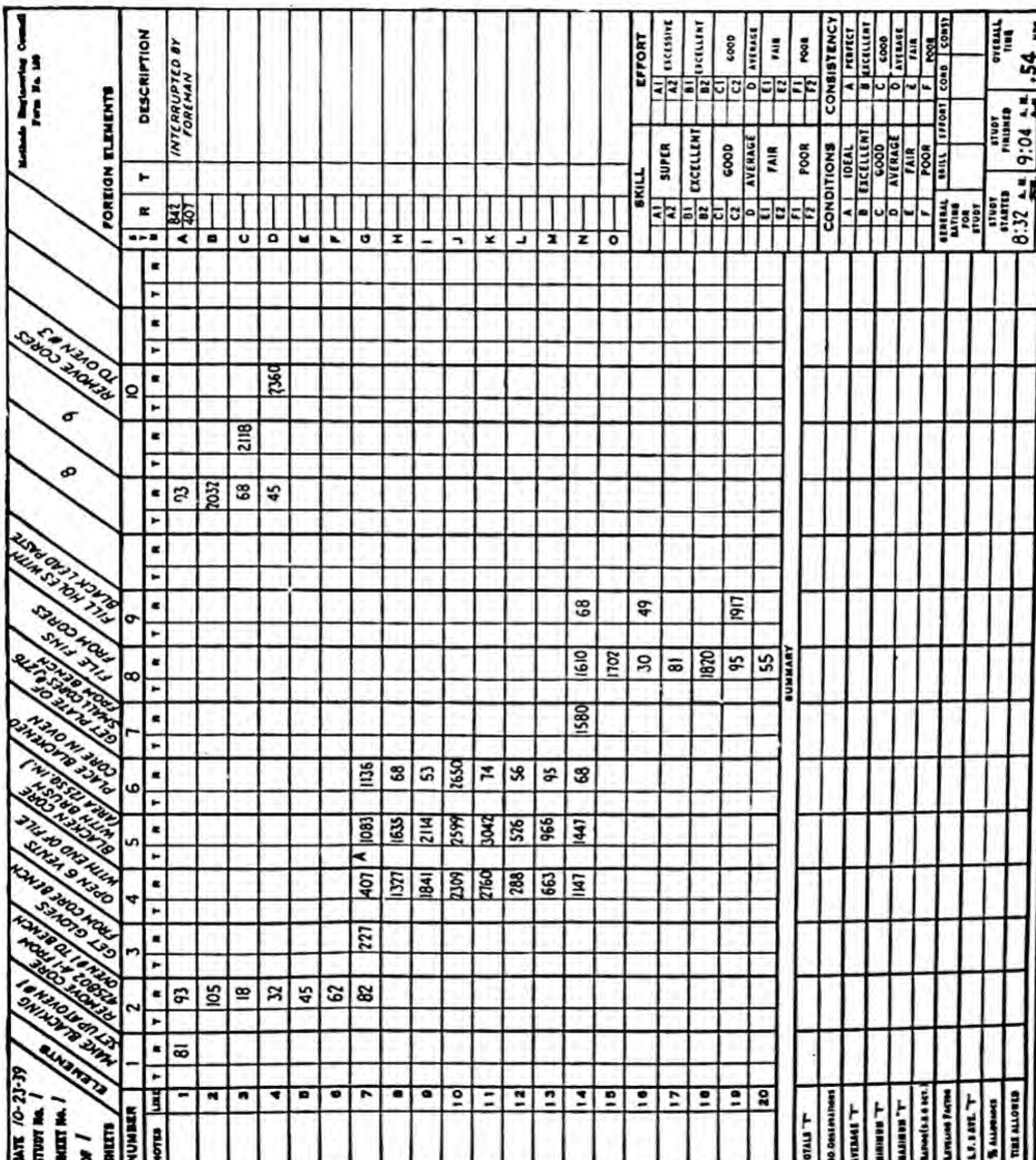


FIG. 95.—See page 188.

observations in a condensed form. Figures 93 to 96 inclusive do not show actual watch readings but only the sequence of recording them, the cycle of numbers being repeated as many times as there are pieces observed.

Figure 93 illustrates the normal arrangement, showing a short operation of 15 elements. Even though some elements may

occur more than once on each piece, it is not necessary to record them vertically, because there is ample room for the full number of elements on each horizontal line. If, however, there had been 24 elements in the cycle, as in the case illustrated in Fig. 94, it would have been impossible to keep the study on one sheet


Methods Engineering Council Form No. 100

DATE 10-23-39 STUDY No. 1 SHEET No. 1 OF 1 SHEETS

ELEMENTS: 1 MAKE BLACKING SET UP AT OVEN #1; 2 REMOVE CORE #25802 A-1 FROM OVEN #1 TO BENCH; 3 GET GLOVES FROM CORE BENCH; 4 OPEN 6 VENTS WITH END OF FILE; 5 BLACKEN CORE WITH BRUSH (AREA 125 SQ. IN.); 6 PLACE BLACKENED CORE IN OVEN; 7 GET PLATE OF SMALL CORES #2276 FROM BENCH; 8 FILE FINS FROM CORES; 9 FILL HOLES WITH BLACK LEAD PASTE; 8; 9; 10 REMOVE CORES TO OVEN #3

LINE	1 R	2 R	3 R	4 R	5 R	6 R	7 R	8 R	9 R		8 R	9 R	10 R
1	81	93									93		
2		105									2032		
3		18									68	2118	
4		32									45		2360
5		45											
6		62											
7		82	227	407	A 1083	1136							
8				1327	1635	68							
9				1841	2114	53							
10				2309	2599	2650							
11				2760	3042	74							
12				288	526	56							
13				663	966	95							
14				1147	1447	68	1580	1610	68				
15								1702					
16								30	49				
17								81					
18								1820					
19								95	1917				
20								55					

FOREIGN ELEMENTS

SYM	R	T	DESCRIPTION
A	842	407	INTERRUPTED BY FOREMAN

SUMMARY: TOTALS "T"; NO. OBSERVATIONS; AVERAGE "T"; MINIMUM "T"; MAXIMUM "T"; RATIO (S.D. & OCT.); LEVELING FACTOR; L.F. × AVE. "T"; % ALLOWANCE; TIME ALLOWED

SKILL: A1 A2 SUPER; B1 B2 EXCELLENT; C1 C2 GOOD; D AVERAGE; E1 E2 FAIR; F1 F2 POOR. EFFORT: A1 A2 EXCESSIVE; B1 B2 EXCELLENT; C1 C2 GOOD; D AVERAGE; E1 E2 FAIR; F1 F2 POOR. CONDITIONS: A IDEAL; B EXCELLENT; C GOOD; D AVERAGE; E FAIR; F POOR. CONSISTENCY: A PERFECT; B EXCELLENT; C GOOD; D AVERAGE; E FAIR; F POOR. GENERAL RATING FOR STUDY: SKILL, EFFORT, COND., CONST.

STUDY STARTED 8:32 A.M. STUDY FINISHED 9:04 A.M. OVERALL TIME .54 HRS

FIG. 96.—Recorded observations of an actual time study showing application of principles illustrated in Figs. 93, 94, and 95.

without recording the repeated elements 5, 6, and 7 vertically. Having repeated elements recorded vertically also facilitates making the summary at the bottom of the sheet.

If it is desired to observe more than 20 pieces for a very short operation, an arrangement similar to that shown in Fig. 95 is

convenient. The example shows how the observations for an operation of seven elements covering 36 pieces can be confined to one sheet.

Figure 96 shows the recorded observations of an actual study in which the principles described above were followed. This example combines features illustrated in both Figs. 94 and 95. The observations of element 2 which was repeated seven times are recorded vertically as are also the group consisting of elements 4, 5, and 6 which was repeated, in the order given, eight times. After the pair of elements 8 and 9 were repeated seven times, bringing the observations to the last line on the sheet, there were still a number of unused vertical columns, so the observer skipped one column and returned to the top of the sheet in accordance with the principle illustrated in Fig. 95. It will be readily seen that this study which has been kept on one sheet would have required no less than four sheets to have recorded horizontally the 50 observations shown, as there are but 15 vertical columns to a sheet. The method which was used in the example given not only makes the observations much easier and confines the entire study to one sheet but it also greatly simplifies the summary and computations.

A good time-study man will exercise his ingenuity in arranging the sequence of elements to the best advantage and in accordance with the demands of the particular job at hand. He will, with practice, be able to visualize how the time-study sheet will appear when the observations are finally recorded and will be influenced accordingly in listing the elements.

The limited space provided on the form for describing the elements calls for a familiarity with the work and for a nice choice of words on the part of the time-study man. Each element must be clearly defined, which means using words and terms which are exactly descriptive and which will preclude the possibility of ambiguity and confusion with another element which is only slightly different. The importance of this point might seem to justify revising the form to provide more space, but the form herein recommended has been used satisfactorily by expert time-study men, and the advantages to be gained by revising this particular feature would be more than offset by the disadvantages of less space for other features. A number of examples of poorly defined elements are listed below with better descriptions opposite:

Poor Descriptions	Better Descriptions
Pick up part	Pick up small part from table
Get drill	Get $\frac{3}{16}$-inch drill from toolroom
Back off table	Back off table 3 inches
File	Ream two mounting holcs with file
Drill hole	Drill hole $\frac{1}{4}$ inch in diameter by $\frac{3}{4}$ inch deep
Get wrench	Get S wrench from drawer
Tape leads	Tape two leads 3 inches
Go to drill press	Walk seven paces to drill press
Turn turret	Turn turret, two positions

Reading the Watch.—Accuracy in reading the watch is developed from practice. A novice will undoubtedly find it difficult to read the watch and record the readings correctly, especially for an operation of many short elements. Unless he has been particularly instructed on the point, he will probably shift his gaze back and forth between watch, operator, and time-study sheet. To look from the watch to the sheet and vice versa is not difficult, because both objects are about the same distance from the eye. To look from the watch to the operator and back again will be found more difficult because of the momentary confusion while refocusing the eyes for the difference in distance. This tiresome eyestrain and tendency toward uncertainty can be greatly relieved by avoiding the actual shifting of the gaze between watch and operator; rather should the eyes be kept directed on the watch. The movements of the operator and terminations of the elements should be observed without actually looking away from the watch. If the observer stands in a proper position and holds his watch so that it comes almost in a direct line from his eye to the operator, it is not necessary for him to take his eyes off the face of the watch in order to see every move made by the worker. The termination of elements is also frequently marked by distinctive sounds, such as laying down a tool, the click of a latch, and the change in sound when a drill breaks through the under side of a metal part or when a cutting tool ceases to cut metal upon arriving at the end of the cut. These can be noted instantly by one who is familiar with the work.

The watch should always be read at the termination of the element. This is generally marked by a sound, as referred to above, or by a reversal of direction or some other decided change in the motions of the operator. Occasionally it is difficult to find a natural division point between two elements, and the time-study man must be unusually careful to take his reading at the same point each time.

Snap-back Method.—One of the two principal ways of making time studies is called the snap-back method. At the termination of each element, the watch is read and as nearly as possible at the same instant the band of the watch is snapped back to zero by pressing the button of the watch. The advantages of this method are that the clerical work of making subtractions which is involved when the continuous method is used is saved and that more observations can be recorded on each time-study sheet. It also facilitates the recording of readings for elements which are performed out of order.

As ordinarily taken, because elapsed times only are recorded, a study made with the snap-back method does not present a clear picture of the sequence in which the elements were performed. Indeed, some engineers do not even record the extent and nature of foreign elements as they occur, but merely stop the watch until the regular sequence is resumed. This makes for incomplete studies and increases the difficulty of selling the time allowance ultimately established to the operator. These difficulties can be overcome, in part at least, by arranging the data on the time-study form in accordance with the principles described above and by timing and recording foreign as well as irregular elements and indicating by symbols at what point they occurred in the study.

An appreciable time is lost in the act of snapping back the hand of the watch to zero at the termination of each element. As the button of the watch is depressed, the hand of the watch flies back to zero almost instantaneously. It requires a measureable amount of time, however, for the time-study man to reverse the direction of his finger or thumb and release the button of the watch. During this time, the hand of the watch is held stationary at zero. In laboratory tests made with the aid of slow-motion pictures, it has been found that the hand of the watch remains stationary from 0.00003 to 0.000097 hour at the time of snap-back, depending upon the speed with which the button of the watch is pressed and released.

This fact means that an error of 3 per cent to over 9 per cent is introduced on each element of 0.0010 hour duration. It is greater on shorter elements and less on longer ones. This error may be partly compensated for by always reading ahead of the hand of the watch, that is, if the hand of the watch at the instant of snapping back is between two divisions, say 0.0009 and 0.0010, the larger reading or 0.0010 is chosen. This reduces the error some-

what, but, if a comparison is made between the overall time of the study as read on the ordinary watch and the sum of all elements on the study, it will be found that the latter figure is some 2 per cent or more smaller than the former. Again an adjustment can be made by increasing the elemental times by this percentage, although this too is inaccurate, for the longer elements will be increased by a greater amount than the shorter, while the time actually lost is constant for each element regardless of its length. If this procedure is followed, one of the most important advantages of the snap-back method is lost; namely, that of saving in the time and labor required to work up the study. In addition, the study is considerably less salable to the average worker.

Continuous Method.—As an alternative to the snap-back method, there is the method wherein the watch is allowed to run continuously from the beginning of the observations to the end. The position of the hand at the termination of each element is mentally noted and recorded, but this reading does not indicate elapsed time for the element. Elapsed time is secured by subtracting successive readings, which is done after the observations have been completed.

The additional clerical work which this method entails may be held to be a disadvantage, but it will be realized that this part of the work can be delegated to a comparatively low-salaried clerk and the slightly increased cost justified by the greater accuracy made possible at the time of the observations. The fact that the watch readings are recorded continuously facilitates checking back over the study for errors. Every moment of time from the beginning of the study to its end is accounted for. This is of considerable advantage in case the time value, which is finally established, is questioned by the workman or anyone else interested. It is possible to point out how the operator employed his time, even including the extent and nature of the delays and unnecessary work.

The continuous method furnishes a ready indication for the time-study man as to whether his stop watch is accurate from a time-keeping standpoint. It is only necessary to compare the final reading with the overall time as determined by his other watch. Because of the superior accuracy and the greater salability of studies taken by the continuous method, the authors have found it somewhat superior to the snap-back method, although it is recognized that good results can be secured from the

snap-back method. The procedure and examples given hereafter, therefore, deal with the continuous method.

Recording Watch Readings.—The hour-decimal watch is read in ten-thousandths of an hour, or to four decimal places. It is not necessary, however, to record all four figures for every element, except when the elements are long enough to extend over one or more complete revolutions of the hand or at the termination of an element during which the hand passed zero. The time for actually writing down the figures is thus reduced to a minimum. The way to record readings can best be illustrated by assuming a series of elements and listing opposite them the full watch readings and these same readings as they would actually be recorded, as shown in the following table:

Element	Full reading, decimal hours	Recorded reading
1	0.0012	12
2	0.0020	20
3	0.0056	56
4	0.0071	71
5	0.0098	98
6	0.0123	123
7	0.0162	62
8	0.0184	84
9	0.0313	313
10	0.0321	21
11	0.0330	30
12	0.0342	42
13	0.0361	61
14	0.0382	82
15	0.0397	97
16	0.1013	1013
17	0.1017	17
18	0.1023	23
19	0.1040	40
20	0.1143	1143
21	0.1154	54

In only three cases in the foregoing example was it necessary to record more than two figures (elements 6, 9, and 16). During element 6, the hand completed its first full revolution in passing from 0.0098 to 0.0123. As it passed zero, the small hand reached the first graduation on the small dial indicating 0.0100 hour. The reading on the small hand need not be recorded again until

another full revolution of the large hand is completed, as it is understood that all intermediate readings are preceded by 0.01 even though it is not shown.

During element 9, the hand passed through zero twice while going from 0.0184 to 0.0313, the elapsed time being 0.0129. Element 16 was the longest of all, extending from 0.0397 to 0.1013. It covered an elapsed time of 0.0616 and was the first case where it was necessary to record four figures.

Variations in Sequence.—After the sequence of elements has been established according to the best arrangement, the time-study man should insist upon this sequence being followed, because any departure from the regular order interferes with the recording of the readings and complicates the study in general. Sometimes, however, variations from the regular sequence are legitimate, and when they occur, the time-study man must be prepared to handle them properly without becoming confused. Variations may be divided into four general classes:

Elements performed out of regular order.
Elements missed by the observer.
Elements omitted by the operator.
Foreign elements.

Elements Performed Out of Order.—Frequently there are combinations of elements in an operation that can be performed equally well in the reverse order from that which has been arbitrarily decided upon, and the operator may thoughtlessly or intentionally reverse the order. If this is not a chronic fault, it is better to record the variation than to interrupt the operator to call it to his attention. The procedure for handling this situation is to draw a horizontal line through the middle of the space for the reading of the element which is being done out of order, record the reading at the beginning of the element (the same as the reading at the end of the preceding element) below the line, and enter the reading at the end of the element above the line. This must be done for each element which is done out of order and for the first operation after the regular sequence is resumed. Element 11, line 3, in Fig. 97, was performed out of order, having followed element 10 instead of the third repetition of element 5, which would have been the regular order. The reading for element 10 was repeated below the line in the space for element 11, and the normal reading for element 11 was placed above the line. This reading which also marks the beginning of element 5 was

placed similarly below the line in element 5 space, and so on. The reading for element 12, the first after resuming the regular sequence, also indicates the beginning of element 1 on the next piece, at which point the normal procedure is again followed.

Methods Engineering Council Form No. 109

DATE 10-4-39 STUDY No. 3 SHEET No. 1 OF 1 SHEETS

NUMBER	1	2	3	4	5	6		7	8	9		10		11	12
ELEMENTS	GET STUD FROM TABLE AND PLACE IN CHUCK	TIGHTEN CHUCK WITH SOCKET WRENCH	START MACHINE	FACE STUD	TURN TURRET ONE POSITION	POINT STUD	5	TURN STUD	TURN TURRET TWO POSITIONS	CHAMFER HEX.	5	THREAD STUD	5	STOP MACHINE	REMOVE STUD AND PLACE IN TOTEPAN
1	18	37	40	78	92	102	12	52	64	78	92	210	20	34	47
2	68	88	92	326	38	49	61	406	18	35	46	72	82	95	508
3	28	48	52	600	10	20	32	73	90	703	14	35	67/51	51/35	77/62
4	802	18	21	66	78	87	98	948	59	75	65	1013	24	42	54
5	73	93	96	M	M	M	1184	1775	37	48	60	79	90	1307	18
6	43	62	66	1412	23	34	43	84	95	1506	17	42	52	66	1600
7	23	33	36	76	87	99	1708	54	67	74	84	1812	—	—	—
8	A 2330	45	49	96	2410	18	30	68	87	94	2504	28	44	62	74
9	94	2614	17	47	57	66	76	2717	28	43	55	78	89	2805	18
10	36	55	58	92	2902	12	23	74	89	3004	16	48	60	82	92
11	110	27	29	60	72	82	93	239	50	64	74	303	15	33	41
12	B 430	73	76	514	27	36	47	93	604	13	24	46	60	71	C 792
13	813	27	30	76	87	97	906	48	59	80	92	1012	24	40	52
14	80	D 1137	40	73	84	90	1202	47	58	M	M	1301	15	33	44
15															
16															
17															
18															
19															
20															

SUMMARY: TOTALS T; NO. OBSERVATIONS; AVERAGE T; MINIMUM T; MAXIMUM T; RATING FACTOR; LEVELING FACTOR; LEVELED T; % ALLOWANCE; TIME ALLOWED

FOREIGN ELEMENTS

SYM.	R	T	DESCRIPTION
A	2312/1812		BREAK STUD
B	405/341		GET 14 STUDS
C	780/671		GET DRINK
D	1123/1085		DROP WRENCH WIPE OFF HANDS
E			
F			
G			
H			
I			
J			
K			
L			
M			
N			
O			

SKILL		EFFORT	
A1, A2	SUPER	A1, A2	EXCESSIVE
B1, B2	EXCELLENT	B1, B2	EXCELLENT
✓ C1, C2	GOOD	✓ C1, C2	GOOD
D	AVERAGE	D	AVERAGE
E1, E2	FAIR	E1, E2	FAIR
F1, F2	POOR	F1, F2	POOR

CONDITIONS		CONSISTENCY	
A	IDEAL	A	PERFECT
B	EXCELLENT	B	EXCELLENT
C	GOOD	C	GOOD
D	AVERAGE	D	AVERAGE
E	FAIR	E	FAIR
F	POOR	F	POOR

GENERAL RATING FOR STUDY: SKILL | EFFORT | COND. | CONST.

STUDY STARTED	STUDY FINISHED	OVERALL TIME
8:46 A.M.	9:12 A.M.	HRS

Fig. 97.—Model time study showing watch readings completed.

Element Omitted by Operator.—This should not occur often, and when it does happen, it probably means that the element was not necessary on that particular piece. If, however, the element is omitted on a large number of pieces, the indications are that it was not necessary at all and should not have been included as a

regular element in the first place. It is taken care of by merely drawing a horizontal line all the way across the column in the space where the reading would have gone, without recording any readings, but going on to the next element as if it had been performed. Element 9, on lines 15, 17, 18, 20, 1, 2, and 4 in Fig. 96, was a case of this kind.

Element Missed by Observer.—The time-study man should not miss or fail to record any watch readings, but sometimes his attention is momentarily distracted from his work or he relaxes his concentration, and before he realizes it, an element is completed, and the time for observing the watch reading has passed.

In a case of this kind, he should not attempt to guess at the reading and record his guess, but he should honestly indicate it as a missed reading. The common symbol for this is an *M* placed in the space where the reading should have gone, as illustrated on line 5 under elements 4, 5, and 6 and in line 14 under elements 9 and 15 in Fig. 97.

Foreign Elements.—It is impossible to anticipate the interruptions and delays which will inevitably occur now and then in the course of a time study. Anything of this kind for which no provision was made at the time the sequence of elements was determined is known as a foreign element. It will be noted that the time-study sheet provides for foreign elements, space having been set aside at the right-hand side of the sheet for this purpose. Sometimes these foreign elements are necessary to the job, and sometimes they are not. An example of a legitimate case would be when, during the time study, the operator found it necessary to replenish his supply of, and perhaps specially to prepare, some particular material necessary to the job. As in the case of omitted elements, necessary foreign elements should not occur frequently, for when a job is thoroughly analyzed and the sequence of elements determined, very few, if any, of those necessary will have been overlooked. Foreign elements also include such departures from the regular sequence as personal requirements, breaking a tool, a slight injury, and unnecessary work. Whether necessary or not, the irregularity must be recorded, and the method of recording it depends upon the way it occurs, of which there are two possibilities. It can happen while a regular element is in progress, thus postponing the completion of that element, or it can happen at the end of one element and before the beginning of the next.

When the time-study man realizes, at the completion of a regular element, that the operator is not performing the next element in the sequence, he will recognize readily whether or not it is a foreign element. If it is, he will indicate the chronological position by placing a symbol in the *T* column of the regular element during which the foreign element is introduced.

It has been found convenient to use as symbols letters of the alphabet placed in the upper part of the space for elapsed time. The foreign elements should be lettered in the order of their occurrence to correspond with the foreign-element symbols printed at the right-hand side of the time-study sheet. The readings at the beginning and at the end of the foreign element will be recorded below and above the horizontal line which divides the space for recording foreign-element readings. The reading below the line will be the same as the reading for the last completed regular element. While the foreign element is in progress, there is generally sufficient time to make a note of what the operator is doing. If the space provided for the description of the foreign element is not adequate, as many additional spaces as are necessary may be used and the symbols for the spaces canceled. The symbol for the next foreign element will be the one following the last canceled symbol. In Fig. 97, foreign elements *B* and *C*, which were performed between regular elements, are recorded in this manner. Foreign element *B* was performed between regular element 12 on the eleventh piece and regular element 1 on the twelfth piece as indicated by the *B* recorded in the first column on line 12. Foreign element *C* was performed between regular elements 11 and 12 on the twelfth piece as indicated by the *C* in the *T* column of element 12 on line 12.

When the foreign element occurs during a regular element, the point at which it occurs is indicated in the same way as described above by placing a reference symbol after the reading for the last completed element to correspond with the next available foreign-element symbol. The same procedure is followed as was just described, except that the reading below the line will not be the same as the reading for the last completed regular element but will be taken at the point where the regular element was interrupted. The reading at the end of the foreign element will be recorded above the line. The regular element which was interrupted is again resumed, and the reading at its termination is

recorded in its proper space. In Fig. 97, on line 14, will be found an example of a foreign element occurring during a regular element. The operator completed element 1 and started on element 2, then interrupted himself, before completing element 2, to perform foreign element *D*, which he completed at 0.1123 as shown at the right-hand side of sheet before resuming element 2, which was finally completed at 0.1137 as recorded in the proper place.

Number of Observations.—The number of pieces to be studied is a matter which cannot be definitely fixed and which must be left largely to the judgment of the observer. This number will be influenced by the length of time required to do one piece and by the number of repetitive elements in each cycle. For instance, an operation of 100 or more elements of which a large percentage are repetitive need not be observed as many times as one of fewer non-repetitive elements. The time-study man should aim to make his study long enough to be representative of normal conditions. The greater the number of observations he has on each element, the more intelligently and accurately can he detect inconsistencies and determine the normal performance time. Beyond a certain point, however, the law of diminishing returns begins to operate, and the advantages do not increase in the same proportion as the time and effort expended in securing additional readings. Generally speaking, 15 or 20 observations are sufficient on operations of several minutes' duration.

Rating Skill and Effort.—The time-study man should note his rating of the skill and effort of the operator in the space provided on the front of the sheet. He should do this before leaving the scene of the work, while the performance of the operator is still fresh in his mind. At this point, the judgment of the time-study man must be at its best, for the calculations to determine standard time will be based upon these ratings. Once these human factors are determined, almost all of the remainder of the work is mathematical. Although these decisions call for keen judgment on the part of the time-study man, it need not be unguided judgment. Two later chapters are devoted to the discussion of skill and effort, and they describe fully the characteristics which determine the different ratings. A careful study of these descriptions will enable the time-study man accurately to classify the skill and effort of the operator.

Summary of Procedure.—For the benefit of the reader and especially of the student reader, there is presented below a brief summary of the different steps in making observations listed in the order in which they should be considered.

1. Arrange and prepare time-study equipment.
2. Stand in a proper position with respect to the operator.
3. Divide the job into its elements and arrange them advantageously on the sheet:
   - *a*. Make elements as short as possible without interfering with accurate observations.
   - *b*. Describe elements exactly.
   - *c*. Assign numbers to the elements in the order of their first occurrence as 1, 2, 3, 4, etc. If an element is repeated after its first occurrence, use the same number that was first used.
4. At the beginning of the first element to be included in the study, start the hour-decimal watch and read the time of day on the ordinary watch.
5. Record the time of day in the space Study Started in the lower right-hand corner of the sheet.
6. Record the hour-decimal watch readings:
   - *a*. At the completion of element 1, record the watch reading on the first line in column 1 under the letter *R*, the reading at the end of the element 2 in column 2 under *R*, and so on.
   - *b*. Record only the necessary significant figures.
   - *c*. Allow the watch to run continuously.
   - *d*. At the completion of the first piece, allow the watch to run and return to column 1, following the same procedure for the second piece as for the first.
   - *e*. Record variations of sequence when the occasion arises and in accordance with the methods previously described in this chapter.
7. Study a sufficient number of pieces to insure a set of data which is representative of the work.
8. At the completion of the last element to be included in the study, record the time of day as indicated on the ordinary watch in the space Study Finished in the lower right-hand corner of the sheet.
9. Make a note of effort and skill on the front of the sheet by checking the term that applies.
10. Sign and date the time study.

CHAPTER XV

INFORMATION

The application of a good time study is by no means limited to the particular job of which it is a record. Although it is justifiable, in most cases, to make a time study solely for the purpose of establishing a time value on that particular job, it may be found later that the time study is of even greater value for reference purposes or for formula construction. If a number of time studies covering a certain class of work have been made, it is often possible to establish the time value on a new job wholly by means of reference to these time studies. Parts of the new job will be found to be repetitions of parts of other jobs previously studied. The time values for certain of these elements can be taken from one study and those for other elements from another study. When time values have been found for all the elements of the new job, the sum may be used as the time value for the job. When a sufficient number of time studies on the same class of work have been made, a formula may be constructed which places all such valuable reference data at the disposal of the time-study man in the condensed form of charts, curves, tables, and algebraic expressions. Part II of this book is devoted to a full treatment of formulas, but it will not be amiss to say here that the value of a time study for reference or formula purposes depends almost wholly upon the accuracy and completeness of the information which identifies and describes the job. A large number of detail time values are, in themselves, of little or no value unless the job to which they apply and the conditions under which the work was done are definitely known. This is possible only when the time-study man has been extremely careful to record all available, necessary, and relevant information at the time or immediately after the study was made. He should not regard his study as completed until this has been done.

After the observations have been made accurately and carefully, nothing should be done that will detract from the reference value of the time study, nor should anything be neglected that

might add to its future value. Time-study information is well chosen and complete if it fully identifies all the features of a job, such as the machine, the operation, the operator, the part, the material, and the tools used, so that the job and conditions

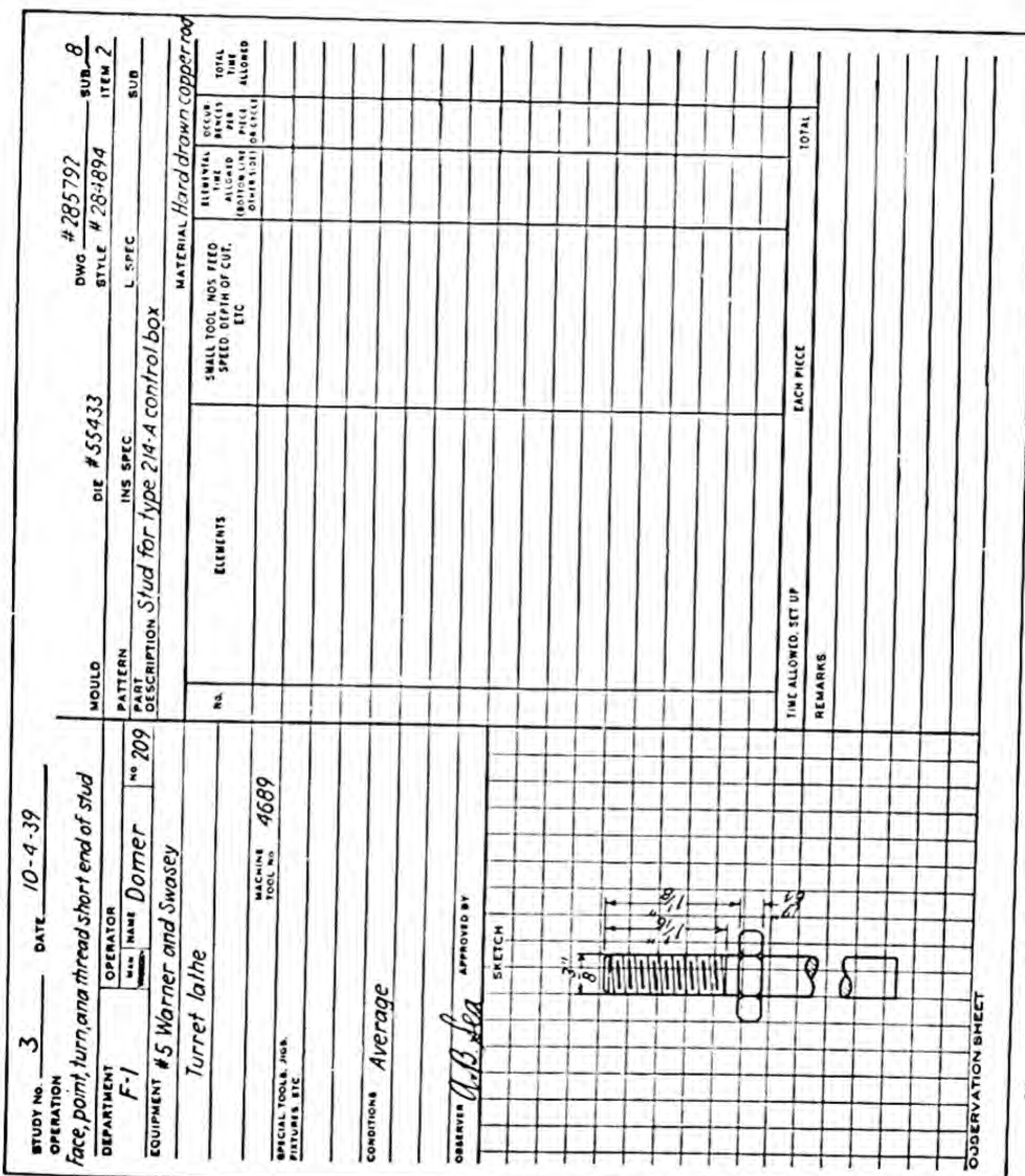


Fig. 98.—Model time study showing information recorded at time of observation.

surrounding and influencing it can be visualized and mentally reconstructed by someone other than the man who made the time study. Figure 98 shows the information recorded on the model time study at the time of observation.

Operation.—The name of the operation should be short and descriptive. It should be common shop usage and not a duplication of the name of any other operation on the same piece or part. Frequently one word will suffice, such as "turn," "bore," "layout," "assemble," "file," "mold," "saw," and "press." Sometimes, however, it is desirable to use a qualifying word as in "rough turn" or "finish turn," when the general term applies equally well to two or more operations on the same piece. Sometimes several general terms are necessary, as "turn, bore, and face" for a turret-lathe or boring-mill operation which is completed during one set-up. Some plants use the system of identifying operations by numbers, in which case, of course, the operation number should be recorded.

Location and Operator.—The information should show specifically where and by whom the operation was performed. Spaces are provided for the department and for the operator. A record should be made of the name and the check number of the operator and whether a man or a woman. This latter point sometimes affects the matter of allowances.

Part.—The part or piece of apparatus upon which the work is being done should be exactly described and identified. It is not sufficient merely to name the part, as "cover," "shaft," "bearing," or "housing," but in addition, there must be given a description of the apparatus for which the part is being made, as "cover for No. 3 gear box," "crankshaft for Type *RS*-7 engine," or "rear-wheel bearing for 1000-pound truck." The name of the part should always correspond with the name which appears in the bill of material on the assembly drawing or on other manufacturing data. In all well-organized plants, parts are identified by number, as "drawing number," "pattern number," "specification number," "style number," or "mold number." All such numbers are, of course, most important, and as many of them as are available should always be noted. Nothing is more definite as the means of identification than a number, and it will be noted that the time-study form provides adequately for them.

A sketch of the part should always be drawn in the space provided. It is not necessary that it be drawn to scale or that it be accurately proportioned like an engineering drawing. A freehand sketch is quite sufficient, but it should be drawn in ink and important dimensions should be shown. The light cross-section

lines will aid in making the different parts of the sketch proportional. The copper stud on which the machining time study given as a model was made is shown by the sketch on the back of the time-study form as illustrated by Fig. 98.

Material.—The material being worked upon should be carefully described, considering such points as kind, weight, grade, shape, dimensions, number, and hardness. Some kinds of material are identified in one way and other kinds in other ways. For example, there are different kinds of steel, as cast steel, cold-rolled steel, and tool steel. Steel rails are graded according to weight and composition, as for example, "90-pound manganese-steel rails," which means that they weigh 90 pounds to the yard and are made of manganese steel. Steel is also furnished in different shapes, as sheets, bars, and tubing, sheets being graded according to gage or thickness and bars according to diameters or other sectional dimensions, as "12-gage C.R.S. sheets," and "3-inch axle steel." Wire is identified according to gage number, as "No. 14 tempered-steel wire."

It is not so essential that the material be as definitely specified on pure assembly work as it is on machining or processing work where the material greatly affects the time for doing certain elements. On the ordinary assembly operations, it makes little, if any, difference in the time required whether brass or steel hardware is used, but if it is a machining operation involving the cutting of the material, it is of considerable importance to know whether the material is brass or steel, because brass can be cut at a much higher speed than can steel. The most efficient cutting speeds, feeds, and depths of cut for different kinds of material may be fairly definitely established so that it will be comparatively easy to check up this point to determine whether maximum efficiency is being secured in this respect. Figure 99 shows in tabular form appropriate milling cutting feeds and speeds for some of the common metals. If the condition of the material is abnormal in any respect, this fact should be noted. Castings are sometimes hard or scaly or have excess finishing allowances. Notation should always be made of any substitution for the material ordinarily used on the job being studied.

Equipment.—The equipment employed on the work should be concisely but fully described. When describing the machine tool, for instance, the time-study man should specify the trade name, size, capacity, class, and type, as for example, "36-inch

F-1 Milling Machines—Feed and Speed Chart

Feed in Inches per Minute

For Brass: Cutting speed of 200 feet per minute

Width of cut, inches	Depth of cut, inches					
	1/16	1/8	3/16	1/4	5/16	3/8
Up to 2	14.4	11.2	9.6	8.0	7.0	6.4
Over 2 to 3	13.5	10.5	9.0	7.5	6.6	6.0
Over 3 to 4	12.6	9.8	8.4	7.0	6.1	5.6
Over 4 to 5	12.0	9.1	7.8	6.5	5.7	5.2
Over 5 to 6	11.0	8.4	7.2	6.0	5.3	4.8
Over 6 to 7	9.9	7.7	6.6	5.5	4.8	4.4
Over 7 to 8	9.0	7.0	6.0	5.0	4.4	4.0

For Cast Iron: Cutting speed of 65 to 75 feet per minute
For Copper: Cutting speed of 200 feet per minute

Width of cut, inches	Depth of cut, inches					
	1/16	1/8	3/16	1/4	5/16	3/8
Up to 2	8.0	7.0	6.5	5.3	5.1	3.4
Over 2 to 3	7.5	6.6	6.0	4.8	4.8	3.2
Over 3 to 4	7.0	6.2	5.6	4.5	4.5	3.0
Over 4 to 5	6.5	5.7	5.2	4.2	4.2	2.6
Over 5 to 6	6.0	5.3	4.8	3.6	3.6	2.4
Over 6 to 7	5.5	4.8	4.4	3.3	3.3	2.2
Over 7 to 8	5.0	4.4	4.0	3.0	3.0	2.0

For Steel: Cutting speed 65 to 75 feet per minute

Width of cut, inches	Depth of cut, inches					
	1/16	1/8	3/16	1/4	5/16	3/8
Up to 2	5.3	4.7	4.0	3.2	2.1	1.6
Over 2 to 3	5.0	4.5	3.8	3.0	1.9	1.5
Over 3 to 4	4.6	4.2	3.5	2.8	1.8	1.4
Over 4 to 5	4.3	3.9	3.3	2.6	1.7	1.3
Over 5 to 6	4.0	3.6	3.0	2.4	1.6	1.2
Over 6 to 7	3.6	3.3	2.7	2.2	1.4	1.1
Over 7 to 8	3.3	3.0	2.5	2.0	1.3	1.0

When using cross-feed of machine No. 20030, use 62½ per cent of tabular feed.
When using cross-feed of machine No. 9845 use 54 per cent of tabular feed.
Note: The width of cut used is the sum of all surfaces machined, as shown in Figs. 1, 2, and 3.

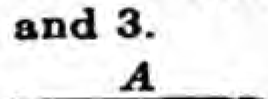


Fig. 1.

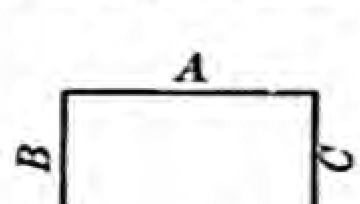


Fig. 2.

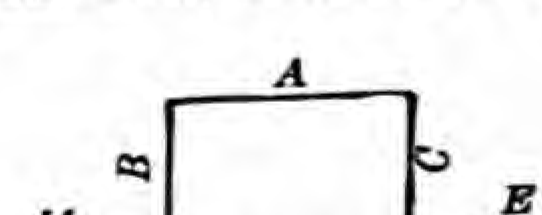


Fig. 3.

Fig. 99.—Speed and feed chart for milling machines

Bullard vertical boring mill," "24-inch Pratt and Whitney turret lathe," or "No. 3 Cincinnati milling machine." If the plant in which the time-study man is employed assigns identification numbers to its machine tools, this number should, of course, be recorded. It is essential that every detail be given regarding the auxiliary tools used such as cutting tools, arbors, jigs, fixtures, and templates. If they are identified by numbers, these numbers should be given as well as descriptions and sizes. Note should be made of how tools are supplied to the workman, whether he is obliged to go to the tool room for them, or whether they are brought to him. The set-up of the machine tool should be described. This can often be done best by means of a sketch

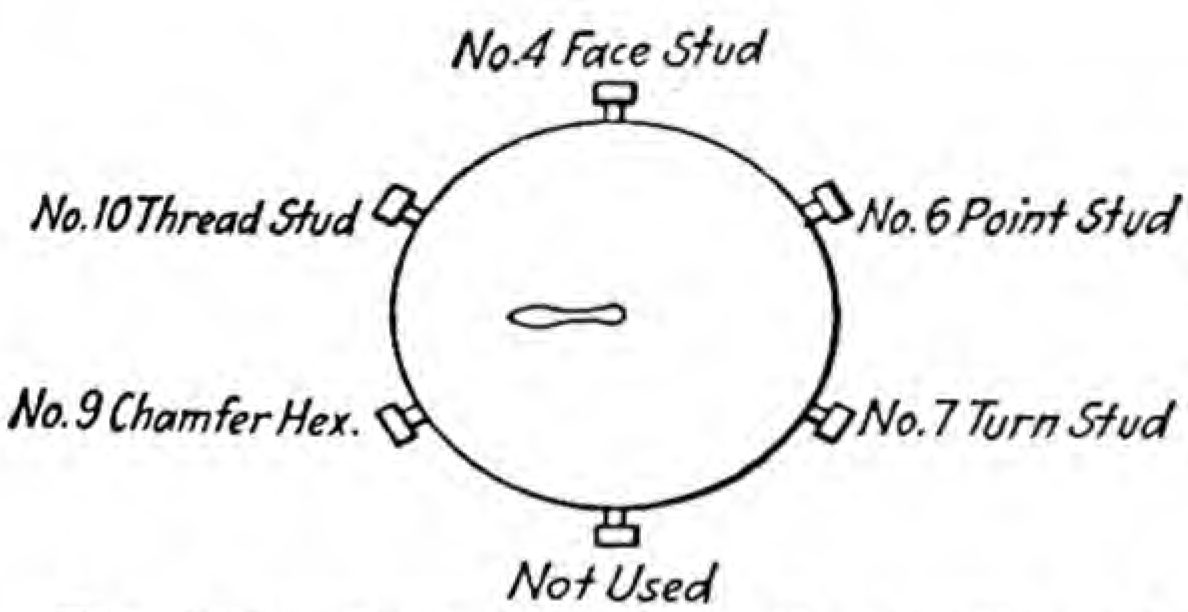


FIG. 100.—Sketch showing the position of tools on the turret as used for performing the operations on which the model time study was made.

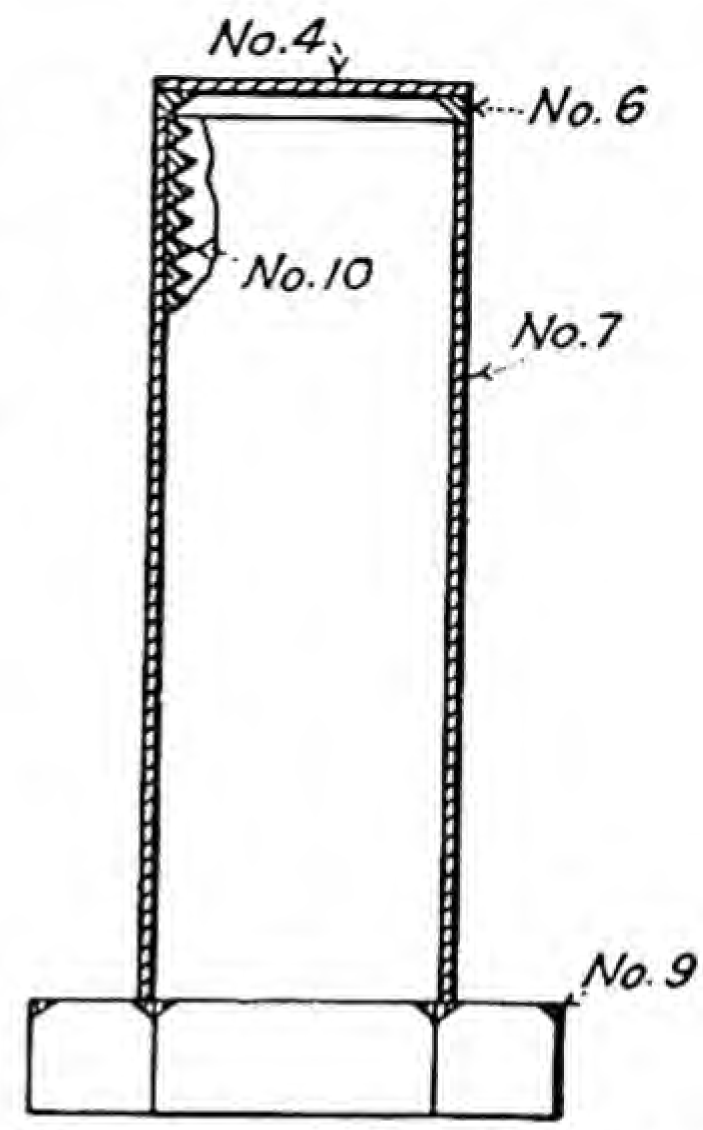


FIG. 101.—Sketch showing the nature of each cut taken on stud on which the model time study was made.

which shows the placing of the tools, methods of holding fixtures to machines, and the like. Figure 100 illustrates how sketches were used to help describe the turret-lathe operation on which the model time study was taken. The arrangement of the tools in the turret is clearly shown, and the elements for which each tool was used are noted. Such a sketch used in conjunction with a sketch of the part as in Fig. 101 aids greatly in visualizing the job, and tells the story more clearly than is possible with words. The sizes and descriptions of all hand tools, such as mallets, pliers, wrenches, and files, should be included in the information recorded on the time-study sheet.

Conditions.—It is important that a record be made of the working conditions existing at the time of the study. If condi-

tions are normal, this fact should be noted, and any abnormal conditions should, of course, be described. The time-study man should note particularly such things as heat, light, and ventilation. This subject has been discussed thoroughly in Chap. VI, "Operation Analysis," and the various factors that should be considered when recording conditions are enumerated there.

CHAPTER XVI

SKILL

The amount of output which a properly qualified operator can produce on a given job depends primarily upon the method which he follows, his skill, the effort which he exerts, and the conditions under which he works. Of these factors, the one which has by far the greatest effect on output is method. In most modern plants, therefore, the tendency is for management to assume the responsibility for method, and after careful motion study and experimentation to specify exactly how each operation is to be performed.

When this has been done, and when all operators have been trained to follow the standard method, it will be found that there are still differences in output, even though the operators are working under conditions which are to all intents and purposes identical. These differences are mainly attributable to skill and effort. Skill and effort materially affect the time taken to perform an operation, and the time-study man should be able to judge skill and effort correctly in order to be able to evaluate properly his time-study data. That this can be done within practical limits has been clearly demonstrated by numerous comparisons of actual production with production standards made over long periods of time. In so far as uniformity of rating among different time-study men is concerned, in investigations conducted by the authors, it has been found that a group of time-study men after proper training can consistently evaluate performance and arrive at results which vary less than plus or minus 5 per cent from the average of the group.

Skill may be defined as *proficiency at following a given method.* It is important that the narrowness of this definition be thoroughly understood. Method is excluded from the concept of skill by this definition. The layman usually associates skill with method, and pictures the skilled man as using the best methods. However, modern methods engineering recognizes no such thing as the one best method. There is the best method devised up to the present moment, but experience has shown that with

detailed study and fresh viewpoints, a given method can be improved again and again. Since a method may, therefore, be regarded as being in a continual state of evolution, it may be seen that method and skill cannot be tied together. An operator may be highly skilled at following a given method. The method itself may or may not be good. If it is considered good today, it may be considered poor six months later, when fresh developments have rendered it obsolete.

Skill or proficiency at following a given method is influenced partly by natural ability and partly by experience or practice. Studies by certain psychologists have revealed large differences in the extent to which various individuals possess various aptitudes. With practice, improvement is effected in performance, but in general, after a given period of practice, the same relative differences remain in a group of individuals as were present at the outset.

Because of this variation among individuals, it is necessary for the time-study man to be able to recognize the skill possessed by the particular individual he is studying, for later on he will wish to convert his data to the basis of average performance for rate-setting purposes. This is not difficult after certain standards for judging skill have been mastered.

Studies of individual differences have shown that the extent of the difference between the best and the poorest individual in a large sampling is about six to one for many of the basic aptitudes. The range within industry is not this great, however, for the employment department ordinarily excludes those in the lowest ranges from the plant, and even if an occasional slip-up occurs, performance on the job shows up the misfit very quickly. There is a certain natural selection process going on all of the time in the industrial organization, and although it is recognized that the more scientific selection process of job qualification measurement is far more desirable, nevertheless it has the effect of narrowing the range of skill existent in the plant.

Skill at any given moment cannot be varied at will by the operator. The operator may slow down or speed up, but this is changing effort. He may introduce fumbles and unnecessary motions in an effort to extend the time for doing the job, but this is changing the method. Skill itself can be increased by practice, or it may be temporarily disturbed by illness, dissipation, or worry, but it cannot be consciously varied from moment to

moment by the operator. This fact explains why the competent time-study man does not have to question the honesty of the operator he is studying or be fearful lest he be misled by a substandard performance. Effort that is less than normal is quite easy to detect, and the time-study man as the result of his detailed methods studies is in the best possible position to know whether or not the proper method is being followed.

The skill which is considered useful industrially may be subdivided into six general classes: poor, fair, average, good, excellent, and superskill. Skill below poor will be excluded either at the employment office or after performance on the job has brought it to light. In fact, skills below average, if they persist after proper training, are usually not countenanced in the well-managed plant.

The characteristics of performance which place an operator within a given skill classification are quite easy to recognize. The following paragraphs describe the characteristics commonly encountered. All of them may not be observed on any one operator, but enough are encountered to make the skill being exhibited clearly recognizable.

Poor.—An operator whose skill would be considered poor is usually one to whom the work is new or one who is unfitted by nature for the work he is doing. In the case of the new man who has not had any previous experience on the work, this lack of knowledge is outstanding. It may be that he is engaged on a machine and his lack of experience makes it necessary for him to stop to think what is to be his next move. After he has decided what it is, he moves with an uncertainty that is quite pronounced. Should he make an error, it will confuse him and may lead him to make more and greater errors. He plainly lacks all the confidence which he will later gain by experience.

Where the skill of an operator is considered to be poor after he has had sufficient time to learn the job, it will generally be found that he is a misfit—the so-called square peg in the round hole. He knows what to do but does not seem able to do it with ease. His movements are clumsy and awkward. His mind and his hands do not seem to coordinate, and before he makes a move, he has to stop to consider whether or not it is right. This man, with all of his seeming care and consideration, turns out an inferior quality of work, makes many mistakes, and spoils more work than those more skilled. Time values should rarely be set from the

performance of an operator of poor skill. The time-study man should recommend that more suitable work be found for him, for experience has shown that every person is fitted by nature for some kind of work. This should be done in fairness to the employee as well as to the employer.

Fair.—The man who may be considered to possess fair skill may be a misfit who has been doing the job for so long that he has been able to overcome some of his natural handicaps and has risen from the poor class. This case is uncommon, however, for if a man is a misfit, he usually will become dissatisfied with his job and will quit before he has been at the work long enough to develop fair skill.

More often, the man is a comparatively new man, but one who has been doing the work long enough to follow the proper sequence of operations without an undue number of blunders. He is still somewhat clumsy and uncertain in his motions, but he seems to have a definite idea of what he is doing. He has become familiar with his place of work, so that his attention is not easily distracted, and he is familiar with the location of machine control levers, supply bins, and the like, so that he does not waste time in hunting.

This man has sufficient knowledge of the work to enable him to plan ahead to a certain extent. He does not hesitate much between operations to think out what he must do next. At the same time, he lacks full self-confidence, because he is still not entirely familiar with the work.

On work which requires a high degree of manual dexterity, this man will find it necessary to spend time repairing mistakes that his lack of skill has caused. A molder who is only fairly skilled will have to devote more time to patching his mold than the skilled man, because he fails to ram his sand properly or because he is clumsy in drawing his pattern and breaks some of the weak sections of the mold.

The fairly skilled man will be better able to read drawings than the man of poor skill. He has become more familiar with the nomenclature used by the plant engineers, and he knows better where to look for finish marks, dimensions, and other guiding information.

Average.—The man who possesses average skill is the one who is most discussed and the one to whom all others are compared. He is the man who has been on the job long enough to be con-

sidered proficient in the work, although he has not been at it long enough to gain that proficiency which comes only through long practice.

He performs the work with reasonable accuracy, and he has confidence in himself. He feels that he has passed the learning stage and is now in a position to be considered a full-fledged artisan on his line of work. He follows a set procedure regularly and will make few mistakes, if any. Experience has taught him the advantage of planning ahead. He understands his tools and equipment, and he is well able to handle them properly. He has lost that clumsiness and uncertainty of movement due to inexperience, and his mind and his hands coordinate so that hesitations are markedly reduced.

This man not only reads drawings proficiently and does the work according to specifications, but he is also able to think out things for himself. The man of average skill will turn out work which is satisfactory in every respect. He will appear a little slow in his motions, but otherwise will give a satisfactory performance.

It should be clearly understood that average skill—and average effort also—is an average established by definition and not mathematically. A given group of operators may all possess greater than average skill, as happens frequently in stable industries where labor turnover is low. On the other hand, in a new plant just starting up all operators might conceivably be below average. In other words, the average skill of a given group has no relation to the average skill as established by definition. The latter describes a fixed level which is the same in every industry and on all operations.

Good.—The man whose skill may be considered as good is noticeably better than the ordinary run of men found doing the same class of work. He seems more intelligent and possesses reasoning ability to a marked degree. He will produce more and better work than the man of average skill with seemingly less effort.

This man is fairly quick in his motions and is sure of himself. He turns out good work and may be counted on always to do it in less than the allowed time unless he has bad material or trouble with his machine or tools. He displays a good knowledge of all tools, equipment, and materials required in the performance of his job and uses them to good advantage. He understands draw-

ings well and can be depended on to make his work correct to specifications.

Operators who have good but not outstanding natural ability develop good skill after being on the job long enough to learn it thoroughly. Of incentive workers in industry studied by or under the direction of the authors, those possessing good skill have been encountered more often than those in any of the other classes.

Excellent.—An operator whose skill may be considered as excellent is distinguished by precision and certainty of action, speed and smoothness of performance, and self-confidence. He is definite and certain and does not make mistakes. He understands machines and tools pertaining to his work and uses every available advantage. His mind and his hands seem to coordinate automatically. He seems to work without effort and is thorough and accurate. He produces a good quantity and quality, far above the less skilled.

This operator has proved himself fitted for the work that he is doing and has gained the knowledge and confidence which is to be expected from one who has had long experience on the same class of work. He is an agreeable type to study, but the time-study man must not fail to take his skill into account. Otherwise, he might discourage the skilled man from using his ability for the advantage of his employer, for he is right in expecting to benefit from his superiority over the less skilled workman. It is not satisfactory to establish time values that only the excellent in skill can meet or better slightly, for then the average operator would fail to meet the time, and he too would be dissatisfied. If the time value is set so that the average man will meet it, and the skilled man materially better it, both will be satisfied. This is a desirable condition, for within the limits of these classes are the great majority of the workers.

Superskill.—The superskilled operator is not common in industry. Superskill comes from long years at the same line of work. The very fact that methods and equipment change frequently, as new and better means are devised, prevents men from becoming highly skilled in more lines of work. In the few cases where the nature of the work is unvarying year after year, men who may be considered as superskilled will be found.

The superskilled operator has all the characteristics of the operator of excellent skill developed to as near perfection as it is

possible for a human being to attain. He knows the job so thoroughly that his motions are steady and as quick as those of a machine. He does not have to think about the work but performs the task like an automaton. His hands seem to fly to the proper places without conscious effort on his part. His motions are so smooth and rapid that they are difficult to follow. One operation blends so smoothly into the next that even an experienced time-study man will have to watch very closely to determine the proper point at which to take his watch readings.

This man stands head and shoulders above the other operators. From the standpoint of the psychological effect on the other workers who may not understand the principle of leveling, it is perhaps best not to time study the superskilled man. The others may feel that the time value arrived at from this study will be so low that they cannot hope to meet it.

Summary.—In order that the salient characteristics which attend each class of skill may be set forth clearly, it will be well to present them in outline form.

Poor Skill:

1. New man or misfit.
2. Unfamiliar with the work.
3. Uncertain of proper sequence of operations.
4. Hesitates between operations.
5. Makes many errors.
6. Movements clumsy and awkward.
7. Does not coordinate mind and hands.
8. Lacks self-confidence.
9. Cannot read drawings well.
10. Unable to think for himself.

Fair Skill:

1. Misfit on job for a long time.
2. Comparatively new man.
3. Follows proper sequence of operations without much hesitating.
4. Somewhat clumsy and uncertain but knows what he is doing.
5. Fairly familiar with equipment and surroundings.
6. Plans ahead to some extent.
7. Lacks full self-confidence.
8. Loses time due to own blunders.
9. Can read drawings fairly well.
10. Gets same output with less effort than poor man.

Average Skill:

1. Works with reasonable accuracy.
2. Has self-confidence.

3. Is proficient at the work.
4. Follows a set procedure without appreciable hesitation.
5. Understands his tools and equipment.
6. Plans ahead.
7. Coordinates hands and mind.
8. Reads drawings well.
9. Appears a little slow in motions.
10. Turns out satisfactory work.

Good Skill:

1. Noticeably better than ordinary run of men.
2. Markedly intelligent.
3. Possesses good reasoning ability.
4. Hesitation entirely eliminated.
5. Needs little supervision.
6. Works at steady pace.
7. Fairly quick in motions.
8. Works correctly to specifications.
9. Can instruct others less skilled.
10. Motions well coordinated.

Excellent Skill:

1. Precision of action.
2. Shows speed and smoothness in performance.
3. Thoroughly familiar with work.
4. Makes no mistakes.
5. Works accurately with little measuring or checking.
6. Operates his machine or tools to best advantage.
7. Works rhythmically and with coordination.
8. Makes speed without sacrificing quality.
9. Has full self-confidence.
10. Possesses high natural aptitude for work at hand.

Superskill:

1. The operator of excellent skill perfected.
2. Has been at the work for years.
3. Naturally suited to the work.
4. Works like a machine.
5. Motions so quick and smooth that they are hard to follow.
6. Does not seem to have to think about what he is doing.
7. Elements of operation blend into one another sc that division points are difficult to recognize.
8. Conspicuously the best worker of all.

Conclusion.—If time-study men do not have a guide for their judgment of skill such as has been given in the preceding paragraphs, often no two of them will agree upon the degree of skill being exhibited by an operator. This is merely because each has

different mental standards by which he judges skill. With the characteristics as given above firmly in mind, two time-study men should form the same opinion of the ability of an operator. This will tend toward consistency in establishing time values.

From the descriptions given, it will be seen that the most important factors to consider in judging skill are hesitations or lack of hesitation, precision or lack of precision of movement, the extent of the interruptions to the normal sequence caused by improper performance, degree of self-confidence possessed by the operator, and general coordination and rhythm of working pace. Other less important factors are also listed. All of these are independent of method. When, as the result of the study of these definitions, plus conscious observation of the proficiency of a number of industrial workers, the standards by which skill is judged are fixed firmly in mind, the time-study man will have little difficulty in deciding upon the skill exhibited upon any kind of work with which he is familiar.

CHAPTER XVII

EFFORT

Output is influenced to a certain extent by the effort exerted by the worker, although perhaps not to the extent commonly supposed. Occasionally, when production increases are desired, an attempt is made to increase working effort by a driving type of supervision. This can only be the result of a lack of appreciation of the factors which increase output. A steady working pace with a minimum of interruption for unnecessary delays is desirable, and incentives which encourage this type of performance are of benefit. The amount of increased output, however, which can be obtained by speeding up the worker over a normal, healthful working pace is unimportant, and much greater gains will be secured if managerial attention is centered on improving working methods.

Effort may be defined simply as *the will to work*. Effort is not related to the amount of foot pounds of work exerted during a given period, but rather to the zest or energy with which the task at hand is undertaken. Effort is controllable at all times by the operator, and poor efforts are given because for one reason or another the operators want to give them. They are evidenced by a slow-motion sort of performance, by an antagonistic attitude, and by an attempt to introduce improper methods, unnecessary work, and numerous interruptions in order to extend the time taken to do the job.

The amount of effort which an operator will put into his work while being studied depends in part upon his attitude toward the company and company policies and in part upon his attitude toward time study and the time-study man. If he feels that the purpose of introducing time study is to get more work out of him for the same or less pay, it is only natural that he should assume an unfavorable attitude. If, on the other hand, the time-study man is a good salesman and can show the man that the true purpose of time study is to establish fair time values under which increased earnings with increased effort are possible, and also

that an honest effort on the part of the operator will help the time-study man to determine such time values, then the operator will be more likely to cooperate and to assist the time-study man to the best of his ability.

Some of the other factors which influence effort are health, physical condition at the moment, interest in the work, general labor attitude at the time, working conditions, mental condition, and distracting elements.

Effort ranges from the point where pure idleness ends up to an excessive working pace which it is unwise to maintain. For industrial purposes, however, the range is reduced in extent by eliminating from consideration the lower levels of effort. The useful range is divided into six general classifications: poor, fair, average, good, excellent, and excessive. The most important characteristics of each are described in the following paragraphs.

Poor.—A poor effort may, theoretically at least, be given by an operator possessing any of the six degrees of skill, but it is more commonly found in company with the lower skill levels. An operator who has stayed on the job long enough to develop high skill usually will have developed an interest in his work and a practical understanding of the company policies. The man of low skill, being either a new man or else a misfit and hence dissatisfied with his job, is more likely to give a poor effort. A poor effort may be malicious, or it may be caused by lack of interest, or it may be, so the operator thinks, given as a matter of self-protection.

A poor effort should be easily detected by the time-study man. It commonly takes one of two forms. It may be evidenced by a lackadaisical, dispirited attitude accompanied by an obviously slowed-down working pace, or it may take the form of a great deal of unnecessary work undertaken with a furious show of energy.

The slowed-down working pace is easy to recognize. The operator goes about his work in slow-motion style, and his attention is concentrated on holding back as much as possible without actually stopping. His intent is so obvious that it tends to induce a feeling of disapproval on the part of the observer whether he be time-study man, supervisor, or fellow worker. This lack of effort is unmistakable, and the only problem is to decide whether or not the slow-down is so great that it carries the performance below the poor level. If it is, it is better to attempt to

improve the attitude of the worker by patient explanation of the purposes of time study or to study another worker, rather than to attempt to guess at the performance level at which the operator is working.

The other form of poor effort, while equally easily detected by the competent time-study man, is more amusing to observe, particularly if it is carried on at all cleverly. It consists of introducing all manner of unnecessary work and of attempting to make the job seem different than it really is. When this is done, a number of the following points will be noticed.

Many trips for tools will be made when one trip should be sufficient. These trips may be made to the toolroom, the operator's own cupboard or workbench, or he may be continually borrowing equipment from fellow workmen. The same will be true of materials and other accessories, for instead of analyzing the job and getting everything required in the fewest possible trips, the operator purposely makes a trip for each separate item. This not only requires extra time to make the extra trips, but it extends the time for doing the other work because, by continually stopping and starting, the operator does not give himself a chance to get into the swing of the work.

Not satisfied with the time lost by unnecessarily running to and fro, he finds it necessary to stop work an unusual number of times to blow his nose, get a drink, or do some other such personal thing. He will interest himself in other things which are apparently out of the ordinary. He will play the part of a good fellow and give fellow workmen advice and demonstrations that are not needed. Sometimes he pretends to be ignorant of things that he should know and has known for a long while and asks questions and seeks advice unnecessarily. Unusual trouble may develop with his tools or the materials, and he will try to engage the time-study man in conversation. He tells him what he is up against and how he can neither get the proper tools nor get his machine repaired. He also says that the material is not what it used to be and that conditions are not right; and he compares his work with what other men are doing elsewhere. He may try to get the time-study man interested in subjects foreign to the work and may try to get sympathy by talking about his family affairs.

Then again, he wants to impress on the time-study man how important is the operation he is performing and how strict accuracy is absolutely necessary, overlooking the fact that the

time-study man has familiarized himself with requirements and the purpose of the operation. He makes many false and unnecessary motions. He does not perform the elements in the same sequence and often starts the same element several times. He makes many mistakes and finds it hard to do anything right the first time but is continually cutting and trying. He will finish the work to a degree of accuracy that is not necessary and that will not be maintained after the time-study man has left; to obtain this accuracy, he will continually gage and measure his work. He will use wrong tools, such as a smooth file when he should use a rough one or a light hammer when a heavy one is more suitable. He may use carbon-steel tools when high-speed steel tools could be used to better advantage, or he may try to use tools that are improperly ground. He resents any suggestions for improvement and intimates that they have been tried before unsuccessfully.

All of these attempts to extend the time are quite obvious to the time-study man who has studied the method in advance. He can therefore do one of two things. He can have a talk with the operator and perhaps his supervisor, pointing out just what is wrong, and suggest that the proper method be followed. This, however, may lead to a demand for an explanation of the proper method, followed by many confusing questions, and a general air of obtuseness. Such a situation seldom produces satisfactory results.

If the method is not too badly confused, the time-study man can make his study, taking out all unnecessary work as foreign elements, and rating the necessary elements with the poor effort rating. This, if properly done, will give a time allowance which is somewhere near the correct one and which is certainly a great deal lower than the operator expected to receive. If he complains about the allowed time, the opportunity is afforded the time-study man of going over the time study with him in detail. He can show how a study is taken, how unnecessary work is recognized and excluded from the final computations, and how skill and effort are adjusted for by leveling. After a thorough, matter-of-fact explanation, the worker will in all probability agree to work properly if the time-study man will make a restudy, and the matter will be settled amicably and with increased respect for the time-study man on the part of the worker.

The amount of space devoted here to the description of the poor effort is by no means in proportion to the frequency with

which it is encountered. Rather, it is rare enough to be outstanding when it is encountered. After workers have had an opportunity to taste of the fairness of time-study methods administered by a just management, the poor effort is seldom encountered.

Fair.—A man exerting a fair effort will be somewhat more reasonable in his accompanying attitude toward his work, but he will exhibit a number of the same tendencies which the man giving a poor effort shows. He takes little interest in his work and seems to regard it as a necessary evil. He makes no suggestions himself as to how the operation may be improved with respect to methods, quality of output, or saving in time, and he receives grudgingly any suggestions that the time-study man may make. After some little persuasion, he may halfheartedly try to make some of the suggested changes, but he evinces throughout a lack of cooperation.

He is inclined to be too accurate in his work and will, unless watched, turn out a better job than the inspection standards require. He grinds his tools, after he has once found them, more often than he should, at the same time explaining how the importance of the job makes this necessary.

Some of the man's seeming lassitude may be due to poor health, late hours, or some mental dissatisfaction or worry. When a man who ordinarily gives a good effort changes and gives only a fair effort, the time-study man should, in a friendly way, try to ascertain just what is the reason. Often he will find that domestic troubles, financial worries, or something of the sort are keeping the man's mind from his work and are thus slowing him up. Perhaps the time-study man may even be able to help him out of his difficulties by a little unbiased counsel and so win his lasting good will.

The man giving a fair effort makes fewer unnecessary motions, although there are still some present. He tries to go about his work in some systematic way, and he gives one the impression that he is really trying to do a fair amount of work. It is readily apparent that he is not doing his best, but at the same time he does not resort to the extreme time-killing practices of the man giving a poor effort.

Generally, the man gives but a fair effort only because he doubts the fairness of the time-study man, or because he does not understand the principles of time study. The time-study man

will in time overcome the doubts in the first case by being absolutely fair in all his dealings with the men in the shop. They will soon realize that he is not trying to get more work from them or to lower their wages, but that he is only trying to do his work as best he can and play fair with both the workmen and his employer. In the second case, a man often thinks that he will get a time value in accordance with the total time he takes to do the job less any time which the time-study man may have felt was spent unnecessarily. For this reason, he tries to extend the time. He takes as much time as possible, feeling that this is the only way he can get a time value which he will be able to better later. A thorough explanation of the principles of leveling should give the man a better understanding of this point and make him more willing to give a better effort thereafter.

On the whole, the man, although slow, puts enough energy into his work so that it is possible to get a usable time study from him.

Average.—The average effort falls on the border line between the fair and the good effort. It is the effort to which all others are compared, and yet it is perhaps the hardest to define specifically. It is a little better than the fair effort and a little below the good.

The operator exerting the average effort works steadily and with fairly good system. He will not deny that he is not doing his best, but he feels justified in holding back because he somewhat doubts the fairness of time study or of the time-study man. These doubts may often be overcome in the manner discussed above.

Lost motions are reduced, and the man appears to take some interest in the work. In short, he shows some of the characteristics of both the man exerting the good effort and the man exerting the fair.

Good.—A man giving a good effort has the following tendencies. He works steadily and systematically and does not lose time doing operations foreign to the work. He takes an interest in the work he is doing and takes pleasure in turning out a good job. He works steadily at a pace which he will be able to maintain day after day and week after week, and his motions have a certain snap or drive to them. He works hard but not hard enough to endanger his health. He is conscientious about his work and when he is not under observation does not try to use

short-cut methods which he knows will detract from the quality of the finished product.

He believes that the time-study man will give him fair treatment, and he is confident that he can more than meet the time value which will be set from the study. When the time-study man starts to time the job, the worker has all his tools at hand, and his work place is in good order. He does not try to deceive the time-study man with regard to the requirements of the job or the methods of doing it; rather he pays no attention to the time-study man but works as if there were no one observing him.

Excellent.—An excellent effort differs from the good effort in several respects. The operator exerting an excellent effort works fast and uses his head as well as his hands. He works with a will and makes his mind direct his efforts to the best advantage. He takes a keen interest in the work. Not only does he readily follow any good suggestions which the time-study man may make, but he is also on the alert himself to better tools and methods through ideas of his own.

This worker reduces false motions to a minimum in so far as his skill permits. He thinks ahead so that he knows just what he is going to do before it is time to do it, and when the time comes, he does it with zeal. He has the utmost confidence in the time-study man and believes that he will receive just treatment at his hands. The time-study man, therefore, feels entirely relieved of the necessity of studying the man and can concentrate his whole attention on studying the actual job.

A man cannot keep up an excellent effort week in and week out, but he can keep it up all day and perhaps for several days. A man who usually gives a good effort will on some days, when he is feeling particularly fit, give an excellent effort. Or it may be that a keen interest in the job he is doing causes him to extend himself more than usual. More often, however, a man will give an excellent effort because of his conscientious desire to be strictly honest with the time-study man. In this case, he will not continue this effort after the time-study man has left.

Excessive.—An excessive effort is given by some few individuals who cannot work normally when anyone is watching them. Perhaps because of a tendency to show off, they extend themselves to a pace which they could not possibly keep up over

an hour or two. Often a few quiet words from the time-study man will calm the worker down so that he will give a more rational effort. This is often advisable, for an excessive effort is quite likely to affect the man's skill. From the consideration of effort alone, the excessive effort is best from every standpoint but that of health.

Summary.—Again it will be advantageous to set forth the characteristics of the six kinds of effort in outline form so that they may be readily available for reference.

Poor Effort:

1. Obviously kills time.
2. Lacks interest in work.
3. Resents suggestions.
4. Works slowly and appears lazy.
5. Attempts to extend time through improper methods by:
   a. Making unnecessary trips for tools and supplies.
   b. Making two motions where one would do.
   c. Having poor set-up or workplace layout.
   d. Doing work more accurately than necessary.
   e. Purposely using wrong or poor tool.

Fair Effort:

1. Same general tendencies but of lessened intensity.
2. Accepts suggestions grudgingly.
3. Attention appears to wander from work.
4. Possibly affected by late hours, dissipation, or mental worries.
5. Puts some energy into work.
6. Method used improper as follows:
   a. Fairly systematic, but does not always follow same sequence.
   b. Still somewhat too accurate.
   c. Makes job unduly hard.
   d. Does not use best tools.
   e. Seems purposely somewhat ignorant of the work at hand.

Average Effort:

1. Better than fair; poorer than good.
2. Works steadily.
3. May somewhat doubt fairness of time-study man or management.
4. Accepts suggestions, but makes none.
5. Seems to hold back his best effort.
6. With respect to method:
   a. Has good set-up.
   b. Plans ahead.
   c. Works with good system.
   d. Reduces lost motions.

Good Effort:

1. Little or no lost time.
2. Takes an interest in the work.
3. Takes no notice of time-study man.
4. Works at best pace suited for endurance.
5. Conscientious about his work.
6. Has faith in time-study man.
7. Encourages advice and suggestions and makes suggestions.
8. Steady and reliable.
9. Follows accepted method:
   a. Well prepared for job and has work place in order.

Excellent Effort:

1. Works fast.
2. Uses head as well as hands.
3. Takes keen interest in work.
4. Receives and makes many suggestions
5. Has utmost confidence in time-study man.
6. Cannot keep up effort more than a few days
7. Endeavors to show superiority.
8. Uses best equipment and methods available, and
   a. Reduces false motions to a minimum.
   b. Works systematically to best of his ability

Excessive Effort:

1. Extends himself to pace impossible to maintain steadily.
2. Best effort from every standpoint but that of health.

Conclusion.—It is just as important for time-study men who work together to have the same standards for judging effort as in the case of skill. It is necessary to consider both skill and effort, for later the results obtained from the performance of the man studied are to be reduced to terms of average skill and average effort. Skill and effort are both used in determining the final results, but when they are being considered during the time study, they should be kept carefully separated. To say that a man who gives the best effort is the man who produces the greatest amount would be utterly meaningless, because skill is not considered.

Theoretically, it is possible for a worker possessing poor skill to work with an excessive effort. Actually, however, if he attempted to apply maximum effort, he would in all probability interfere with what little skill he possessed in his attempt to hurry. Ordinarily, it is not customary to find a given degree of

skill accompanied by an effort more than two classes higher or lower than the skill class, or vice versa. In other words, poor efforts tend to accompany poor skills and high efforts, high skills. An operator of average skill might work with poor effort or excellent effort, but it would be more common to find him exerting a fair, average, or good effort. The differences encountered, however, are sufficient to preclude the possibility of rating performance on either factor alone.

CHAPTER XVIII

COMPUTATIONS AND SUMMARY

With the observations and the information recorded, the remainder of the work necessary to complete the time study and to determine the allowed time for the job confines itself almost entirely to calculations and mathematical procedure. A good share of this work is of such a routine nature that it may be delegated to a clerk, although it must be borne in mind that accuracy is essential. On the face of the time-study sheet, alternate columns headed with T will appear blank. The figures in the columns headed with R represent the watch readings which were recorded at the terminations of the elements.

Subtractions.—The first step of the computations is to determine elemental elapsed times by subtracting successive watch readings. These subtractions are recorded in the blank columns, each one in the space between the two watch readings that determine its value. Elapsed time should be noted in ink both to insure a permanent record and to distinguish it from the watch readings.

Referring to Fig. 97, which illustrates the appearance of the time study at the completion of the observations, it will be noted that the first reading is 18, or to express the full decimal, 0.0018. The watch having been started at zero at the beginning of this element, the elapsed time will naturally be the same as the watch reading or 18 as recorded in Fig. 102 under T in column 1. Proceeding to element 2 in Fig. 102, it will be seen that the watch reading is 37. The elapsed time for element 2 is then the difference between 18 and 37, or 19, which is recorded under T in column 2. By continuing in this manner throughout the time study, subtracting each reading from the succeeding one and recording the result between the two, the elapsed time for every occurrence of each element is readily determined. Figure 102 shows the appearance of the time-study sheet after the subtractions are completed.

Variations in Sequence.—Those irregularities that called for special consideration when the observations were being recorded also demand somewhat of a variation from the usual method as just described when making the subtractions. Where a space

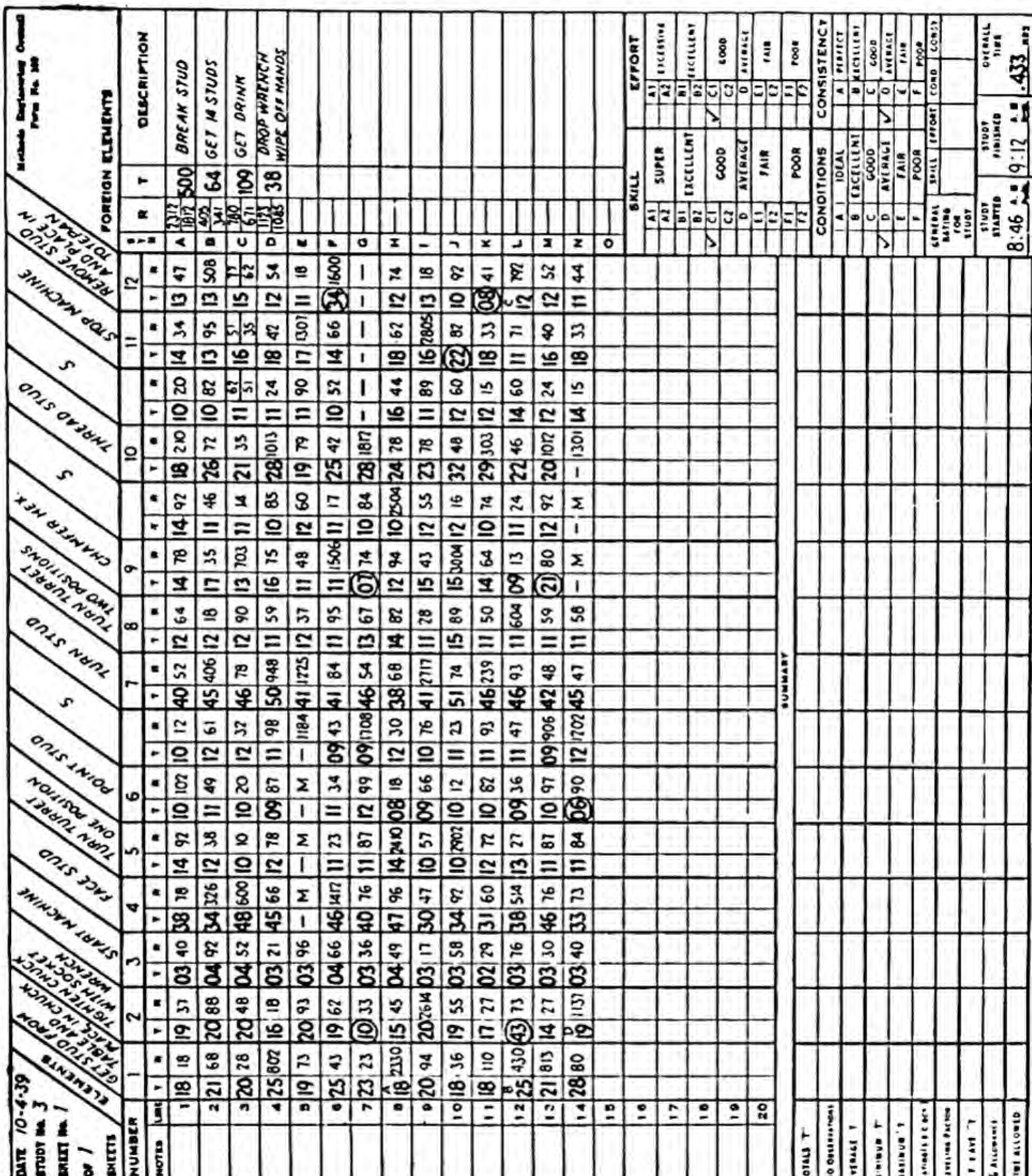


Fig. 102.—Model time study showing subtractions completed.

contains two watch readings separated by a horizontal line, the elapsed time is determined by subtracting the lower reading from the upper one. This applies to foreign elements as well as those appearing in the body of the study.

A horizontal line in a space without any watch readings indicates that the element was omitted by the operator. This

element may be disregarded entirely. The elapsed time for the next completed element will be found by subtracting from the reading for this element the watch reading for the element which immediately preceded the one not performed.

An *M* indicates that the watch reading was missed by the observer. Obviously the elapsed time cannot be determined for the missed element nor for the one that follows it, so the corresponding spaces must be left blank.

When a letter indicating a foreign element is encountered, the duplicate printed symbol in the first column under Foreign Elements on the right-hand side of the sheet should be referred to. The elapsed time of the foreign element will be found by subtracting the lower reading from the upper one, and this value deducted from the total elapsed time for the regular element will leave the net or correct duration. During element 2 on line 14 in Fig. 102, a foreign element occurred. The total elapsed time for element 2 was the difference between 0.1080 and 0.1137, or 0.0057. But the *D* indicates that a foreign element must be deducted from this 0.0057. At the right under *D*, it is found that the foreign element was begun at 0.1085, the reading below the line, and ended at 0.1123, the reading above the line, giving an elapsed time of 0.0038. Deducting 0.0038 from 0.0057, the net or elapsed time for element 2 becomes 0.0019. This is recorded as shown.

Abnormal Values.—Before taking up the summary of the elapsed times, the time study should be carefully examined for abnormal values. If any are found, they should be indicated so that they can be readily distinguished and excluded from the summary. A convenient method is to circle them as shown in Fig. 102 under element 2 in lines 7 and 12. A value is regarded as abnormal when it is extremely high or low as compared to the majority of the other values for the same element. No definite rule can be established for determining when values are abnormal, because the allowable variation from normal will vary with the length of the element. For instance, in a series of 20 observations ranging in value from 0.0002 hour as the lowest to 0.0008 hour as the highest, 0.0002 hour would be abnormal if it had occurred but once and the other 19 values ranged from 0.0005 to 0.0008 hour. If, however, 19 of these values had ranged from 0.0002 to 0.0004 hour, then 0.0002 hour would be considered normal while 0.0008 hour would be abnormal. Picking out the abnormal values is largely a matter of judgment in which there is

little likelihood of error, for extreme cases will be obvious at a glance, and doubtful cases will not show sufficient variations to change the result materially whether the values are admitted to the summary or not. To illustrate this point, three examples are presented below.

Order of occurrence	*A* Elapsed times	*B* Elapsed times	*C* Elapsed times
1	8	93	2
2	11	98	3
3	9	101	4
4	22	108	3
5	10	83	3
6	8	83	4
7	10	85	3
8	11	93	3
9	10	100	4
10	10	50	2
11	9	118	3
12	6	98	3
13	9	93	3
14	14	71	5
15	8	83	5
16	9	87	4
17	9	82	6
18	8	103	4
19	10	94	4
20	9	85	3
Total............	0.0178 hour	0.1808 hour	0.0071 hour
Number of occurrences..........	19	19	20
Average..........	0.000936 hour	0.00951 hour	0.00035 hour

In example *A* the fourth value, 0.0022 hour, is obviously abnormal and is excluded at once. Closer study may raise the question as to whether the next highest value, 0.0014 hour, should be left in, and looking still further the twelfth occurrence, 0.0006 hour, may seem abnormally low. There is just about as much reason for excluding one as the other, but if they are both out, the result is not greatly changed. The total becomes 0.0158 hour instead of 0.0178 hour. This new total divided by 17, the number of occurrences, gives an average of 0.000929 hour instead of 0.000936 hour or a decrease of seven-tenths of 1 per cent.

Practically, there would be no change, for the decimal is ordinarily carried out to only four places. Hence, the result in both cases would be 0.0009 hour.

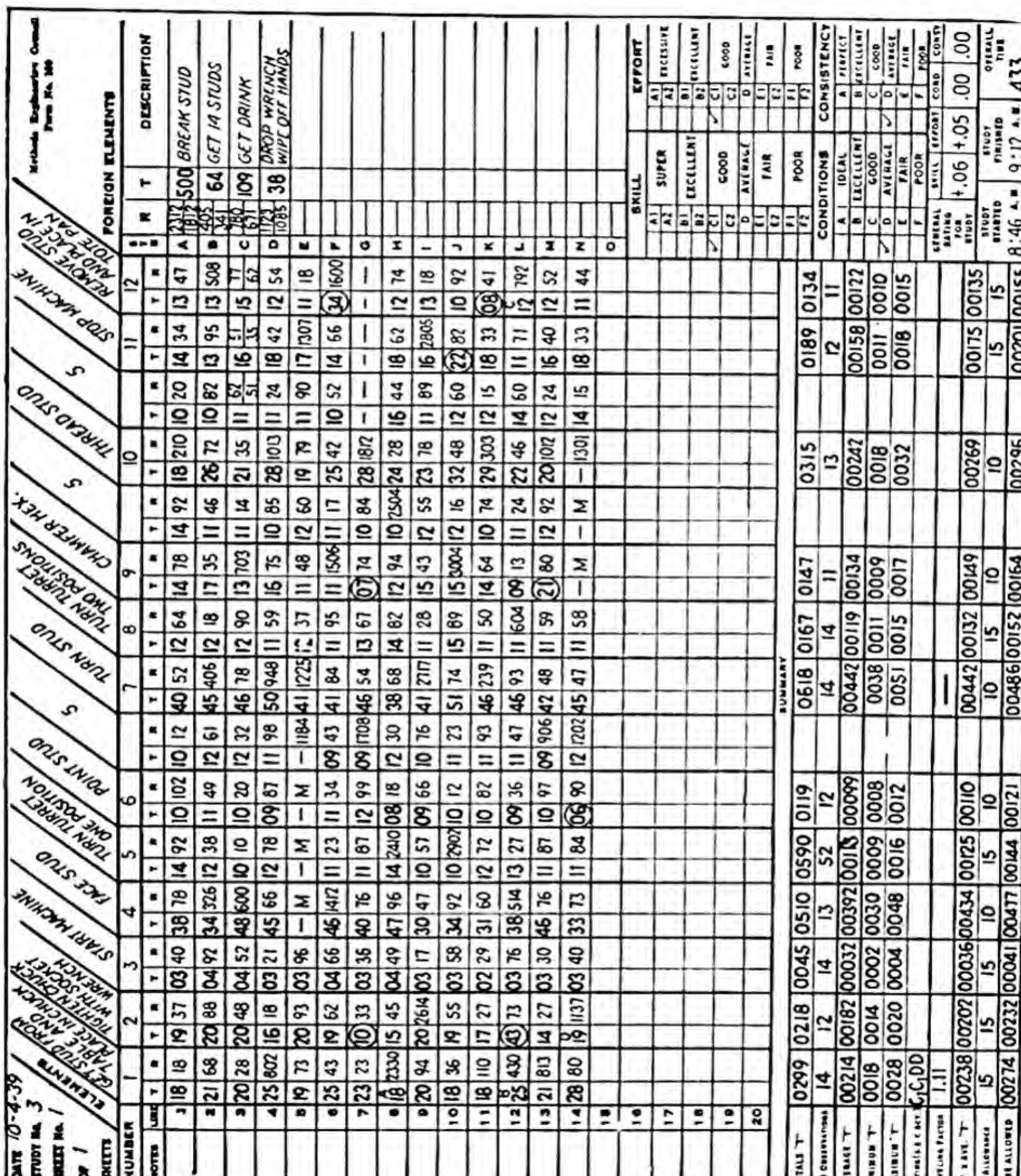
The same is true of example *B* in which the tenth value, 0.0050 hour, is obviously too low and is excluded at once. Here, as in example *A*, one might question 0.0118 hour and 0.0071 hour, which are the eleventh and fourteenth values, but by carrying out the calculations it is again found the result is not appreciably affected by taking them out. With these two values omitted, the total becomes 0.1619 hour instead of 0.1808 hour, and the average becomes 0.00952 hour instead of 0.00951 hour. By dropping the fifth decimal place, both values become 0.0095 hour.

In example *C* the first occurrence, 0.0002 hour, and the seventeenth occurrence, 0.0006 hour, are both somewhat abnormal. When they are used in the summary, the average is 0.00035 hour, and when they are omitted, the average is still 0.00035 hour.

It is better, therefore, to exclude only those values that are extreme and readily recognized as abnormal. If there are too many values discarded, the time-study man throws himself open to the possible criticism that his study is not representative of conditions as they actually were when the observations were made. There is generally a good reason for abnormal values, and the time studies of an alert and competent observer will seldom contain any, because he will have discerned and noted the causes while making the observations. Low values are frequently caused by an element being only partially performed either due to neglect of the operator, or because the condition of the material or some other feature of the job is unusually favorable for quick performance. High values are generally caused by some unusual difficulty, as a bad piece of material, or by some small foreign operation which escaped the notice of the observer and was not recorded.

Number of Occurrences.—After the abnormal values are eliminated, the next step is to count the number of occurrences for each element and record the number in the space provided under Summary at the bottom of the sheet. If more than one column has been used for an element, the values appearing in all of them should be summarized together in the first column devoted to the element. This applies also to the recording of the number of occurrences. No summary will appear, then, in any

of the columns to follow that have been used for the element in question, but instead of a summary there should be shown the element number appearing at the head of the summary column. It is a simple matter to recognize repetitive elements, provided the repetitions were designated at the time of observation by



Methods Engineering Council Form No. 100

DATE 10-4-39 STUDY No. 3 SHEET No. 1 OF 1 SHEETS

NUMBER	1		2		3		4		5		6				7		8		9				10				11		12	
ELEMENTS	GET STUD FROM TABLE AND PLACE IN CHUCK		TIGHTEN CHUCK WITH SOCKET WRENCH		START MACHINE		FACE STUD		TURN TURRET ONE POSITION		POINT STUD		S		TURN STUD		TURN TURRET TWO POSITIONS		CHAMFER HEX.		S		THREAD STUD		S		STOP MACHINE		REMOVE STUD AND PLACE IN TOTE PAN	
LINE	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R
1	18	18	19	37	03	40	38	78	14	92	10	102	10	12	40	52	12	64	14	78	14	92	18	210	10	20	14	34	13	47
2	21	68	20	88	04	92	34	326	12	38	11	49	12	61	45	406	12	18	17	35	11	46	26	72	10	82	13	95	13	508
3	20	28	20	48	04	52	48	600	10	10	10	20	12	32	46	78	12	90	13	703	11	14	21	35	11	62/51	16	51/35	15	77/62
4	25	802	16	18	03	21	45	66	12	78	09	87	11	98	50	948	11	59	16	75	10	85	28	1013	11	24	18	42	12	54
5	19	73	20	93	03	96	—	M	—	M	—	M	—	1184	41	1225	12	37	11	48	12	60	19	79	11	90	17	1307	11	18
6	25	43	19	62	04	66	46	1412	11	23	11	34	09	43	41	84	11	95	11	1506	11	17	25	42	10	52	14	66	34	1600
7	23	23	10	33	03	36	40	76	11	87	12	99	09	1708	46	54	13	67	07	74	10	84	28	1812	—	—	—	—	—	—
8	A 18	2330	15	45	04	49	47	96	14	2410	08	18	12	30	38	68	14	82	12	94	10	2504	24	28	16	44	18	62	12	74
9	20	94	20	2614	03	17	30	47	10	57	09	66	10	76	41	2717	11	28	15	43	12	55	23	78	11	89	16	2805	13	18
10	18	36	19	55	03	58	34	92	10	2907	10	12	11	23	51	74	15	89	15	3004	12	16	32	48	12	60	22	82	10	92
11	18	110	17	27	02	29	31	60	12	72	10	82	11	93	46	239	11	50	14	64	10	74	29	303	12	15	18	33	08	41
12	B 25	430	43	73	03	76	38	514	13	27	09	36	11	47	46	93	11	604	09	13	11	24	22	46	14	60	11	71	C 12	792
13	21	813	14	27	03	30	46	76	11	87	10	97	09	906	42	48	11	59	21	80	12	92	20	1012	12	24	16	40	12	52
14	28	80	D 19	1137	03	40	33	73	11	84	06	90	12	1202	45	47	11	58	—	M	—	M	—	1301	14	15	18	33	11	44
15																														
16																														
17																														
18																														
19																														
20																														

SUMMARY

	1	2	3	4	5	6		7	8	9		10		11	12
TOTALS T	0299	0218	0045	0510	0590	0119		0618	0167	0147		0315		0189	0134
NO. OBSERVATIONS	14	12	14	13	52	12		14	14	11		13		12	11
AVERAGE T	00214	00182	00032	00392	00113	00099		00442	00119	00134		00242		00158	00122
MINIMUM T	0018	0014	0002	0030	0009	0008		0038	0011	0009		0018		0011	0010
MAXIMUM T	0028	0020	0004	0048	0016	0012		0051	0015	0017		0032		0018	0015
RATINGS S.E.C. & CY.	C_1C_1DD														
LEVELING FACTOR	1.11							—							
L.F. × AVE. T	00238	00202	00036	00434	00125	00110		00442	00132	00149		00269		00175	00135
% ALLOWANCE	15	15	15	10	15	10		10	15	10		10		15	15
TIME ALLOWED	00274	00232	00041	00477	00144	00121		00486	00152	00164		00296		00201	00155

FOREIGN ELEMENTS

SYM.	R	T	DESCRIPTION
A	2312/1812	500	BREAK STUD
B	405/341	64	GET 14 STUDS
C	780/671	109	GET DRINK
D	1123/1085	38	DROP WRENCH WIPE OFF HANDS
E			
F			
G			
H			
I			
J			
K			
L			
M			
N			
O			

SKILL		EFFORT	
A1, A2	SUPER	A1, A2	EXCESSIVE
B1, B2	EXCELLENT	B1, B2	EXCELLENT
✓ C1, C2	GOOD	✓ C1, C2	GOOD
D	AVERAGE	D	AVERAGE
E1, E2	FAIR	E1, E2	FAIR
F1, F2	POOR	F1, F2	POOR

CONDITIONS		CONSISTENCY	
A	IDEAL	A	PERFECT
B	EXCELLENT	B	EXCELLENT
C	GOOD	C	GOOD
✓ D	AVERAGE	✓ D	AVERAGE
E	FAIR	E	FAIR
F	POOR	F	POOR

GENERAL RATING FOR STUDY	SKILL	EFFORT	COND.	CONST.
	+.06	+.05	.00	.00

STUDY STARTED	STUDY FINISHED	OVERALL TIME
8:46 A.M.	9:12 A.M.	.433 HRS.

FIG. 103.—Model time study showing summary and computations of elemental allowed times completed.

placing the number, which was first used to identify the element, at the tops of the columns devoted to the repeated elements.

Totals of Elapsed Times.—The time-study man himself should indicate the abnormal values, and he should also count and record the number of occurrences for each element, but the matter of

adding the elapsed time for each element and finding the average elapsed time are calculations that can very well be assigned to a reliable clerk. Determining the totals of the elapsed times for each element is a comptometer or adding-machine operation. The main point to watch is that all occurrences, up to the

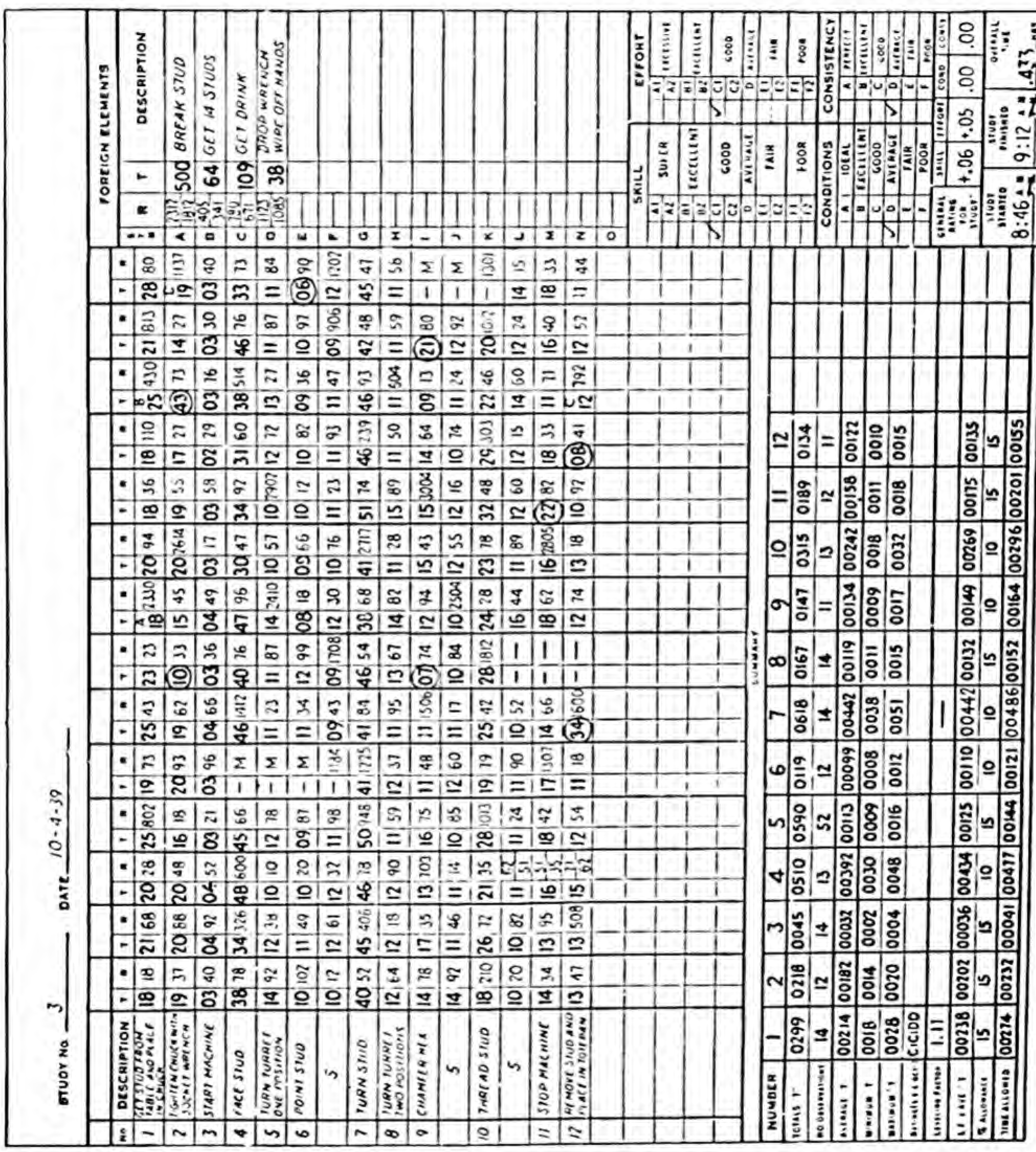


FIG. 104.—Model time study as it would appear on a form of the vertical-column type, showing the same data as that shown in Fig. 103.

number that has been indicated by the time-study man, have been included in the total. The full decimal, to four places, should be shown in this total, it being understood that the whole numbers expressing elapsed times indicate ten thousandths of an hour.

Average, Minimum, and Maximum Elapsed Times.—The totals of the elemental elapsed times should be divided by the number of occurrences as recorded by the time-study man. The results are the average elapsed times which may be taken to represent the performance level of the operator on that particular study. To these average elapsed times are applied the appropriate leveling factors. For example, in Fig. 103, the total of the elapsed times for element 1 was 0.0299 hour. This divided by

Skill			Effort		
+0.15	*A*1	Superskill	+0.13	*A*1	Excessive
+0.13	*A*2		+0.12	*A*2	
+0.11	*B*1	Excellent	+0.10	*B*1	Excellent
+0.08	*B*2		+0.08	*B*2	
+0.06	*C*1	Good	+0.05	*C*1	Good
+0.03	*C*2		+0.02	*C*2	
0.00	*D*	Average	0.00	*D*	Average
−0.05	*E*1	Fair	−0.04	*E*1	Fair
−0.10	*E*2		−0.08	*E*2	
−0.16	*F*1	Poor	−0.12	*F*1	Poor
−0.22	*F*2		−0.17	*F*2	
Conditions			**Consistency**		
+0.06	*A*	Ideal	+0.04	*A*	Perfect
+0.04	*B*	Excellent	+0.03	*B*	Excellent
+0.02	*C*	Good	+0.01	*C*	Good
0.00	*D*	Average	0.00	*D*	Average
−0.03	*E*	Fair	−0.02	*E*	Fair
−0.07	*F*	Poor	−0.04	*F*	Poor

FIG. 105.—Performance-rating table.

14, the number of times that element 1 occurred in the whole study, gave an average elapsed time of 0.00214 hour. Since this average time is to be multiplied by a leveling factor and then increased by an allowance percentage, it is well, for the sake of accuracy, to carry as many places as can be conveniently read on a slide rule. The final time value or the allowed time for each element need be given only to the nearest fourth decimal place.

By glancing over the list of elapsed-time values, the minimum or lowest time in which each element was performed is readily apparent. These values should be recorded on the fourth line of the summary. Likewise, the maximum values should be

selected and recorded on the fifth line. These values are not actually used to determine the final allowed time, but they are convenient for reference purposes, and too a great difference in them may justify further investigation.

Performance rating	Numerical equivalents	Sum to be added to 1.0	Leveling factor
Excellent skill Good effort Average conditions Good consistency *B*2, *C*1, *D*, *C*	+0.08 + 0.05 + 0.00 + 0.01	0.14	1.14
Average skill Excellent effort Good conditions Good consistency *D*, *B*1, *C*, *C*	+0.00 + 0.10 + 0.02 + 0.01	0.13	1.13
Excellent skill Poor effort Good conditions Fair consistency *B*1, *F*1, *C*, *E*	+0.11 − 0.12 + 0.02 − 0.02	−0.01	0.99
Poor skill Good effort Average conditions Poor consistency *F*1, *C*1, *D*, *F*	−0.16 + 0.05 + 0.00 − 0.04	−0.15	0.85
Average skill Fair effort Average conditions Fair consistency *D*, *E*1, *D*, *E*	0.00 − 0.04 + 0.00 − 0.02	−0.06	0.94
Average skill Average effort Average conditions Average consistency *D*, *D*, *D*, *D*	0.00 + 0.00 + 0.00 + 0.00	0.00	1.00

Leveling Factor.—The factor by which the average time is multiplied in order to adjust for difference in performance above

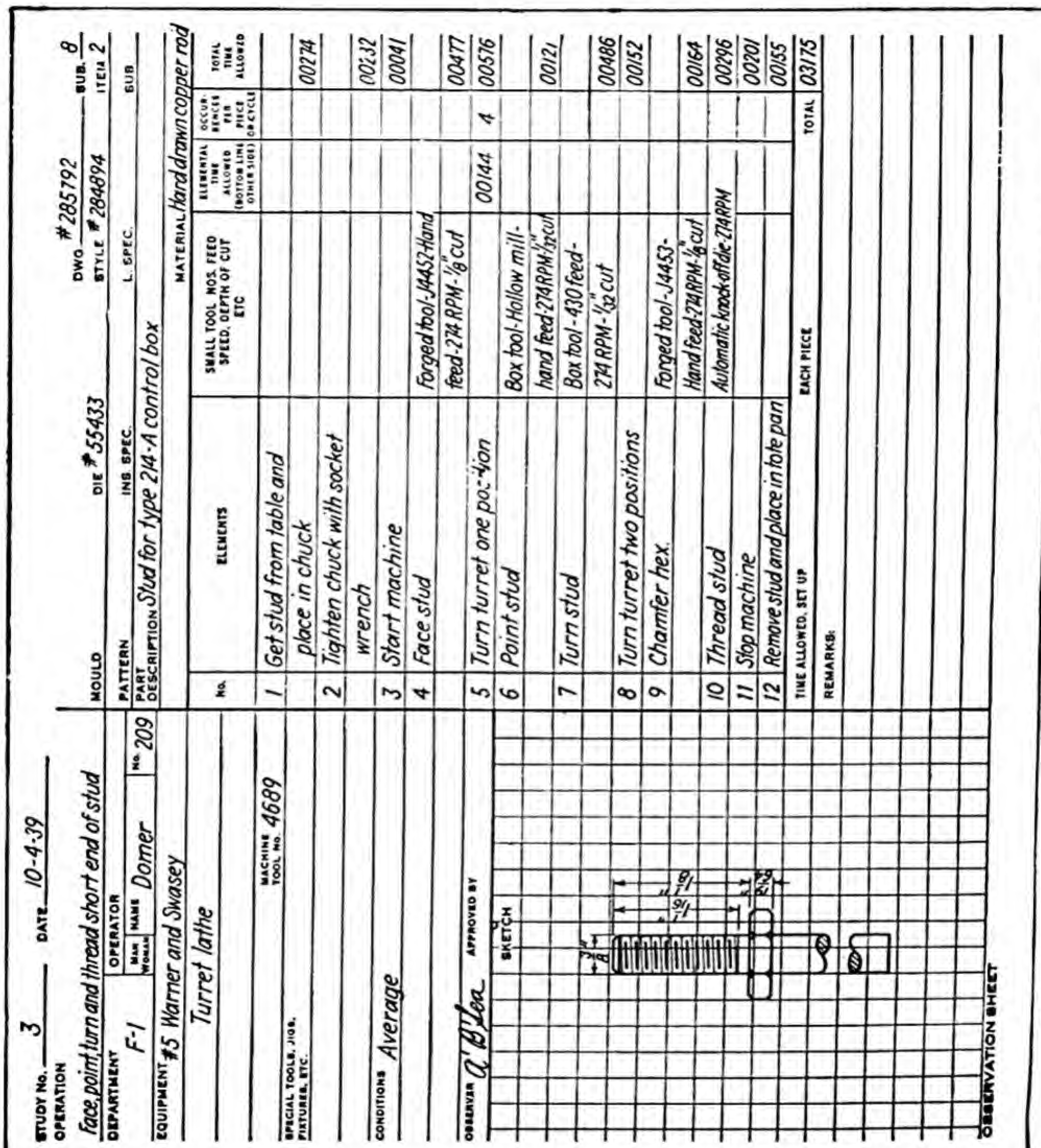
or below average is called the leveling factor. The value of this factor is influenced by four things: skill, effort, conditions, and consistency. By referring to the lower right-hand corner of the sheet, the general rating of these four points will be found. Except for those elements that have been individually rated, this general rating will be used for the entire study. Exceptions will have been indicated in appropriate columns in the seventh line of the summary. Each symbol used to express this rating has a corresponding numerical value as shown on the Performance-rating Table (see Fig. 105). The algebraic sum of these numerical values added to 1.0 will give the leveling factor which should be recorded in the space reserved for that purpose. If a general rating has been applied to the entire study, there will be, of course, a general leveling factor. In this case, it is not necessary to record it for every element. The examples given on the preceding page illustrate the method of arriving at the leveling factor.

L. F. × Ave. T.—At this point, the leveling principle which is explained in detail in the next chapter is applied. As previously explained, the average time represents the actual performance level and includes, in the aggregate, all of the effects of variations from normal skill, normal effort, normal conditions, and normal consistency. Each average elapsed time is multiplied by the appropriate leveling factor, and the result is recorded in the eighth line of the summary.

Allowances.—If workers were able to work continuously, the leveled time would be the correct value to allow, but constant application to the job is neither possible nor desirable. In the course of a day, there are bound to be occasional interruptions and delays, for which due allowance must be made in establishing the time value. These allowances are determined by the time-study man in accordance with the methods set forth in a succeeding chapter. Each element should be considered separately and the appropriate allowance recorded in the next to the last line in terms of a percentage by which the standard time is to be increased.

Time Allowed.—The time allowed for each element is recorded in the last line of the summary in decimal hours. It is the result after the leveled time has been increased by the allowance percentage. This value becomes a part of the allowed time for the operation as calculated on the back of the sheet.

Back of Time-study Sheet.—The numbers and descriptions of the elements should be transcribed in ink on the back of the sheet. The majority of future references will be made to this part of the time study. Descriptions of the elements may be


STUDY No. 3 DATE 10-4-39
OPERATION Face, point, turn and thread short end of stud
DEPARTMENT F-1 OPERATOR MAN/WOMAN NAME Domer No. 209
EQUIPMENT #5 Warner and Swasey Turret lathe
MACHINE TOOL No. 4689
SPECIAL TOOLS, JIGS, FIXTURES, ETC.
CONDITIONS Average
OBSERVER A. O'B'Lea APPROVED BY
SKETCH
OBSERVATION SHEET
MOULD DIE #55433 DWG #285792 SUB. 8
PATTERN INS. SPEC. STYLE #284894 ITEM 2
PART DESCRIPTION Stud for type 214-A control box L. SPEC. SUB
MATERIAL Hard drawn copper rod

No.	Elements	Small tool nos. feed speed, depth of cut etc.	Elemental time allowed (bottom line other side)	Occurrences per piece or cycle	Total time allowed
1	Get stud from table and place in chuck				00274
2	Tighten chuck with socket wrench				00232
3	Start machine				00041
4	Face stud	Forged tool-J4452-Hand feed-274 RPM-1/8" cut			00477
5	Turn turret one position		00144	4	00576
6	Point stud	Box tool-Hollow mill-hand feed-274 RPM-1/32" cut			00121
7	Turn stud	Box tool-430 feed-274 RPM-1/32" cut			00486
8	Turn turret two positions				00152
9	Chamfer hex.	Forged tool-J4453-Hand feed-274 RPM-1/8" cut			00164
10	Thread stud	Automatic knock-off die-274 RPM			00296
11	Stop machine				00201
12	Remove stud and place in tote pan				00155
TIME ALLOWED, SET UP		EACH PIECE		TOTAL	03175

REMARKS:

Fig. 106.—Model time study showing back of sheet completely filled out.

elaborated upon if it will add to the clearness. It is well at this time again to check briefly the information and the sketches to see that everything is as complete as possible. The time allowed for each element is transcribed to the column reserved for that purpose. In the next column to the right should be noted the number of times the element occurs on one piece or cycle of the

operation. Extensions of the total time allowed for each element should be made and recorded in the last column. Elements that occur but once will be carried over as they appear in the Time Allowed column. The time allowed for those occurring more than once will be multiplied by the number of times they occur and the product carried over. The allowed time for the operation is then the sum of the items in the last column. Figure 106 shows the model time study with the back of the sheet completely filled out. A full discussion of allowed time will be found in Chap. XXI.

CHAPTER XIX

DETERMINATION OF STANDARD TIMES BY LEVELING

Assuming that the observations have been made accurately, the most important step in time-study procedure is the determining of the standard time. The standard time which is established from a time study taken on any job should be the time that is required by an operator who possesses average skill and training when he is working at an average pace under average conditions. It represents the time required to do the job at the average performance level. It is not the allowed time which would be established for use in connection with incentives, however, for certain additional allowances for fatigue and personal and unavoidable delays must be added, as will be shown in the next chapter.

In establishing the standard time, the greatest care and judgment must be exercised, for at this stage everything which influences the time value must be taken into account. The experienced observer, who is acquainted with the character of the work and with effective and efficient methods of performing simple manual and mechanical operations and who is also a keen student of human nature, will soon learn to recognize with certainty any tendency on the part of the operators to do other than that which should be expected of them and to make allowances accordingly.

Reasons for Leveling.—Considering then that different operators possess varying degrees of skill and that they will differ in the effort given, in order that the time standard established from a time study for any degree of skill or effort may be a standard representing average performance, it is necessary to use some method of adjustment of the recorded elemental times if the operator studied gave other than an average performance. It is evident that if, on the basis of an operator whose skill is good and who has put forth a good effort, a time standard were established such that he could just meet it or gain on it slightly, the less

skilled operator would fail to meet it even though he might put a good effort into his work. Or, on the other hand, assume that the time standard is established, without taking skill and effort into account, from a study taken on a less skilled operator who gave only a fair effort. Then, he will just meet this time, but when he improves his effort he will gain on or beat the time to an extent to which he is hardly entitled, and the time will be far too liberal for the more skilled operator.

This can be best illustrated by a simple example. Assume that two men working as molders in a foundry are molding the same part, and using the same method. The time-study man studies both operators on the same number of molds, and he finds that one operator is much more skilled than the other and that the more skilled operator gives the better effort. Consequently, there is a large difference in the time taken by each to make the same number of molds. The questions are: Which time study should be used and how could a time value be arrived at from either study which would be correct for both operators? The answer is that there must be some method of bringing the results obtained from both operators to the same level, some method which will bring about the same results that would be obtained if there were no difference in skill and effort of operators. Without some such method, time study would be of little value as a means of setting accurate time standards. With a method of adjustment of the elemental elapsed times, it really does not matter which study is used or whether one or ten studies have been taken, for it is expected that the trained observer will establish the same time standard regardless of the type of operator he has studied, provided the same method was being used. The extent to which the observer can accomplish this is, of course, dependent on the accuracy and thoroughness of the adjustment method used.

Effect of Skill and Effort upon Performance Level.—Suppose for a moment that it is possible to find a man working with an average performance on an operation which the time-study man wishes to study. This man will possess average skill and will work with an average effort. Assuming that conditions are average, the times for each element of the operation obtained from a study of this man will be the standard times which it is desired to determine. The study will be taken on a number of pieces, and while the time value determined for a given element

will not be exactly the same for every piece because of minor differences in materials, motions, and performance level impossible to detect, the average of these times, after abnormal values have been set aside, will give for that element the standard time that the operator may be expected to meet consistently. In other words, the average of the elapsed times for each element will determine the plane along which the operator possessing average skill will continuously work while giving an average effort. The leveled time values for all operations in the plant should be along this plane.

In most cases, however, it will not be possible to find a man working with average performance. Suppose, rather, that it is necessary to study a man who, although working with an average

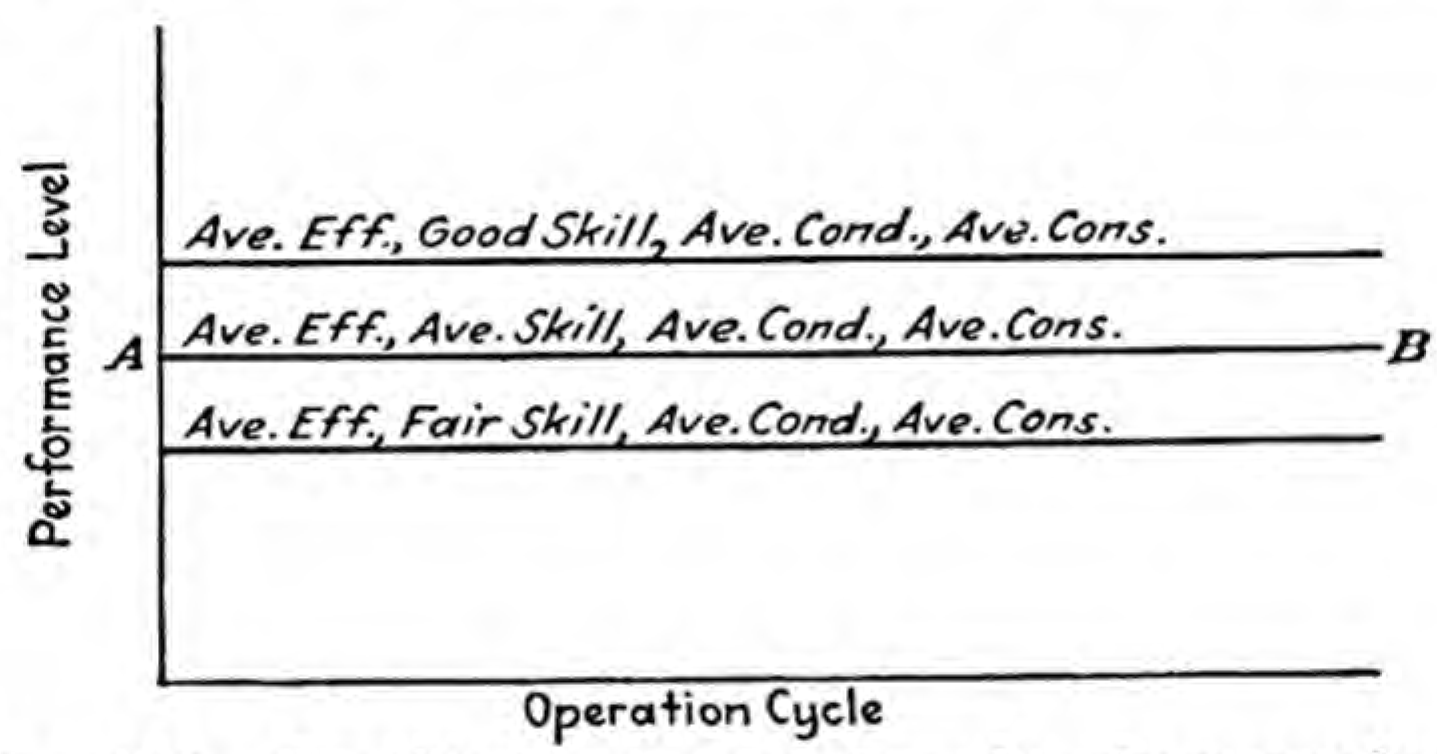


FIG. 107.—Graphical representation of performance level.

effort, possesses good skill. Because of this higher degree of skill, the average elemental time values determined from the study will be lower than those obtained from the man working at the average performance level. This second man will work along a higher plane than will the average.

Similarly, if another man, working with an average effort but possessing only fair skill, be studied, the time values obtained will be higher than those of the average performance, for this man will be working on a plane below the average. These levels are shown graphically in Fig. 107. The standard time values as set from the time study should lie along the performance level AB, since this will allow the man working with average performance just to meet the established time. In the last two cases considered, the level obtained does not coincide with the level AB because these two operators differed from the average operator in respect to skill.

Again, consider three operators all of whom possess average skill, but who, when working under average conditions, exert varying degrees of effort. If one man is giving an average performance and hence is exerting an average effort, his average plane will be along AB. If the second man exerts a good effort, he will perform the operation faster than the first man will, and his performance level will be relatively higher. Lastly, the third man exerting only a fair effort will be working along a plane lower than AB.

Conditions.—In addition to skill and effort, working conditions have some effect upon the output from a given method. The conditions which can be adjusted for by leveling are those which affect the operator and not those which affect the operation. Conditions which affect the operator are such things as light, heat, and ventilation. For example, on a Monday morning in winter the plant may be unusually cold due to lack of heat in the buildings over the week-end. The hands and fingers of the operator may be somewhat stiffened by cold causing him to take somewhat longer to do the job than if he were exerting the same effort under normal conditions, his skill, of course, being constant under any conditions. Therefore, it is necessary to make some adjustment to compensate for the effect of the poor and unusual conditions which exist at the particular moment the study is being taken.

In another instance, a clogged water line on a tool grinder may make it necessary for the operator to go 200 feet to get a can of water before grinding his tool and then to grind the tool holding it in one hand only while with the other hand he pours the water on the wheel. This represents poor conditions in one sense of the word, to be sure, but not in the sense used in connection with leveling. Such conditions affect the operation, not the operator. They cause a change in method, and variations in method cannot be adjusted for by leveling.

Conditions are judged in relation to the conditions which normally prevail in the place where the work is being done. Conditions in a pickling department may be poor when compared to the conditions in an air-conditioned office, but if they are the conditions under which the work must be done day in and day out, they are average in so far as that department is concerned. The same remarks apply to comparisons between plants. One plant may provide conditions which are better than another, but

the prevailing conditions in each plant would be classed as average regardless of the fact that they might be entirely different. The reason for this is apparent. Conditions affect the performance of the worker, but they are out of his control. If he is given consistently unfavorable conditions under which to work, his performance level will be consistently lower than if management improved conditions. As far as he is concerned, however, his performance reflects the conditions under which he must work, and if the same conditions prevail day in and day out, they must be considered average. On the majority of all time studies taken, conditions will be rated as average.

Consistency.—When subtractions are made in working up the study, it will be found that the elapsed times for a given element are not all exactly the same. A certain amount of variation is unavoidable. Even on operations which are mechanically controlled and for which the elapsed time is known to be constant, the elapsed times as determined by a stop watch will not be exactly the same due to the fact that the watch is read to only the nearest one-hundredth division of the dial.

On operations which are not mechanically controlled, the variation may be expected to be greater. The amount of variation which may be considered normal depends upon the nature of the element. The element "start machine" which consists merely of extending the hand to a control box and pushing a button should be performed in about the same time whenever it is done, providing the operator has developed a steady working rhythm. The element "pick up lock washer from bin" will vary considerably, for sometimes a lock washer will be picked up without difficulty, and at other times the washer grasped will be tangled with others and must be separated.

In judging consistency, therefore, the nature of the element should be considered. It must also be weighed in the light of the skill and effort of the operator. Operators of high skill usually work more consistently than less skilled operators. At the same time, high effort tends to disturb consistency, particularly if the operator is not highly skilled. If, after all these factors have been taken into account, an element is judged to be unduly inconsistent, the reason for the inconsistency should be sought. Inconsistency usually indicates that there is something wrong with the operator or the operation, and it is better to discover the trouble and correct it than to try to adjust for it by the application of a leveling

factor. The factors for consistency are provided, however, to call attention to the necessity of reviewing consistency on every study made, and to allow the time-study man to adjust the performance level slightly up or down if, in his judgment, the consistency of the data indicates that it should be done.

Determination of Level.—When skill, effort, conditions, and consistency have been determined, the next step is to find the exact level which these four factors locate. This may be done with the aid of either the Performance-rating Table shown in Fig. 105 or the Performance-rating Chart (Fig. 108). The Per-

Conditions			Consistency		
+0.06	A	Ideal	+0.04	A	Perfect
+0.04	B	Excellent	+0.03	B	Excellent
+0.02	C	Good	+0.01	C	Good
0.00	D	Average	0.00	D	Average
−0.03	E	Fair	−0.02	E	Fair
−0.07	F	Poor	−0.04	F	Poor

To determine leveling factor, add algebraically values from above table to factor read from curves below.

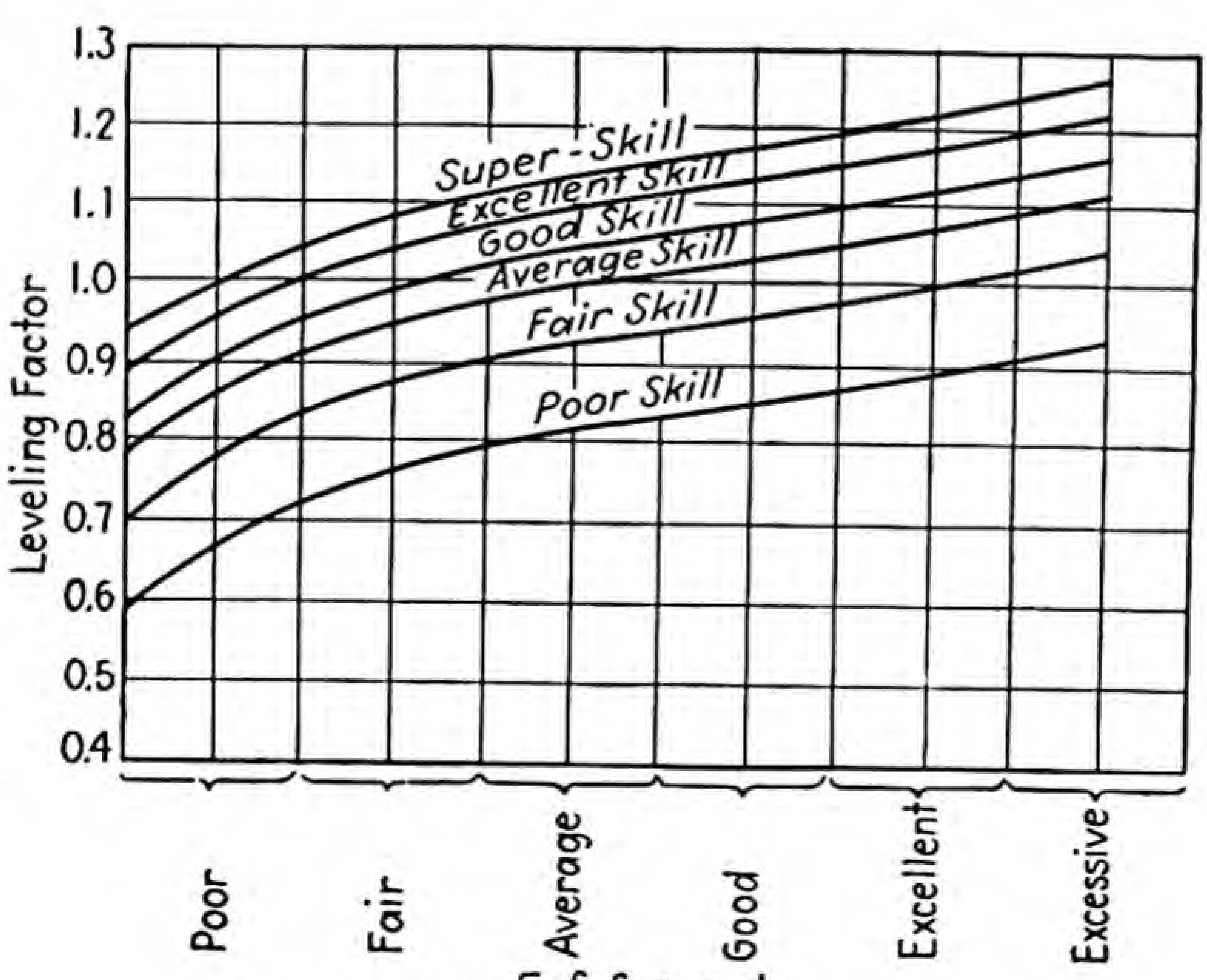


FIG. 108.—Performance-rating chart.

formance-rating Table gives numerical values which when added together algebraically give the proper leveling factor to use for any given combination of the four variables. Under each different degree of skill and effort except "average," two numerical values are given. For example, under superskill, the values +0.15 and +0.13 are given. In the column immediately adjoining, the symbols *A*1 and *A*2 are shown. These symbols correspond to those given on the face of the time-study form. The symbols containing the number 1 refer to degrees of skill or effort which are slightly better than those described by the definitions given in Chaps. XVI and XVII, but which are still somewhat below the standards set for the next highest subdivision. Similarly, the symbols bearing the number 2 refer to slightly poorer degrees of skill or effort than those given by the definitions. *A*1, then, in the skill column designates a skill outstanding in every respect, while *A*2 refers to a degree of skill which, while better than excellent skill, is on a par slightly below that described by the definition of superskill. Midway between the two falls the degree of skill given by the definition, and the numerical figure used is the average of the two given in the table. In the case of superskill, this is the average of +0.15 and +0.13, or +0.14.

At the time of taking the study, the time-study man records on the face of the time-study form his judgment of the skill and effort exhibited by the worker. This he does by placing a check mark opposite the proper symbol. If the operator works with an effort which is slightly better than fair and shows average skill, the time-study man will place a check mark opposite *E*1 in the effort column and opposite *D* in the skill column. If the effort exactly corresponds with that designated by the standard definition, the time-study man should circle both numbers 1 and 2, thus indicating that the average of the two values given in the Performance-rating Table is to be used. This method of considering degrees of skill and effort slightly above or below those given by the definitions makes it possible to rate an operator as closely as human judgment permits.

The Performance-rating Chart, Fig. 108, shows graphically the relation between skill and effort and illustrates clearly the fundamental principles upon which the leveling method is based. Effort is used as the base against which the leveling factor as determined by skill and effort alone is plotted for each of the six degrees of skill. For the sake of clearness, curves of degrees

slightly above or below those considered as standard are omitted. The effect of conditions and consistency on the leveling factor as determined from the curves is given by the table at the top of the chart.

The Performance-rating Table and the Performance-rating Chart are, of course, interchangeable. The chart is slightly more flexible, while, on the other hand, values may be determined from the table with greater exactitude. Thus, it will be found that the table is better for everyday use.

The chart, however, illustrates more clearly the following basic principles: For a given effort a man's output will vary as his skill, and for a given degree of skill his output will vary with the effort expended according to the law of diminishing returns; that is, up to a certain point, return is proportional to expenditure, but beyond that point, the addition of another unit of expenditure will bring a lesser return than did the preceding unit. Applied to effort, performance level for a given degree of skill will be very nearly proportional to the effort expended, except that in the lower stages of effort one unit of increase in effort will raise the performance level more than will a similar unit of increase in the higher stages of effort.

On the chart, the lines of skill are plotted according to the law of diminishing returns, and these lines are also spaced according to this law. Thus, the difference in level caused by changing from poor to fair skill is greater than that caused by changing from good to excellent skill.

The paths of the curves given on the chart were determined from a number of time studies taken under varying conditions on men who differed in skill and effort. For example, the difference between a man working under average conditions with a good effort and possessing fair skill and a man under poor conditions showing average effort with good skill was accurately determined by studying each when doing exactly the same operation of drilling two holes in an iron casting. Similar studies were taken over work ranging from cleaning rough castings to complex coil building, and thus the curves are truly representative.

The curves which are shown on the chart are only those portions of curves which are usable for time-study purposes. Actually, there are many degrees of effort worse than that defined as poor. The worst effort possible would, of course, be exhibited by the operator who is practically idle and who does little if any

useful work. From this effort, there is a considerable range before the poor effort is reached. Thus, for example, the complete curve of average skill would appear as in Fig. 109. For time-study work, only the portion *ab* is considered. Care must be used to make sure that any operator studied meets at least the definition of poor effort. Similar reasoning holds true in the case of skill.

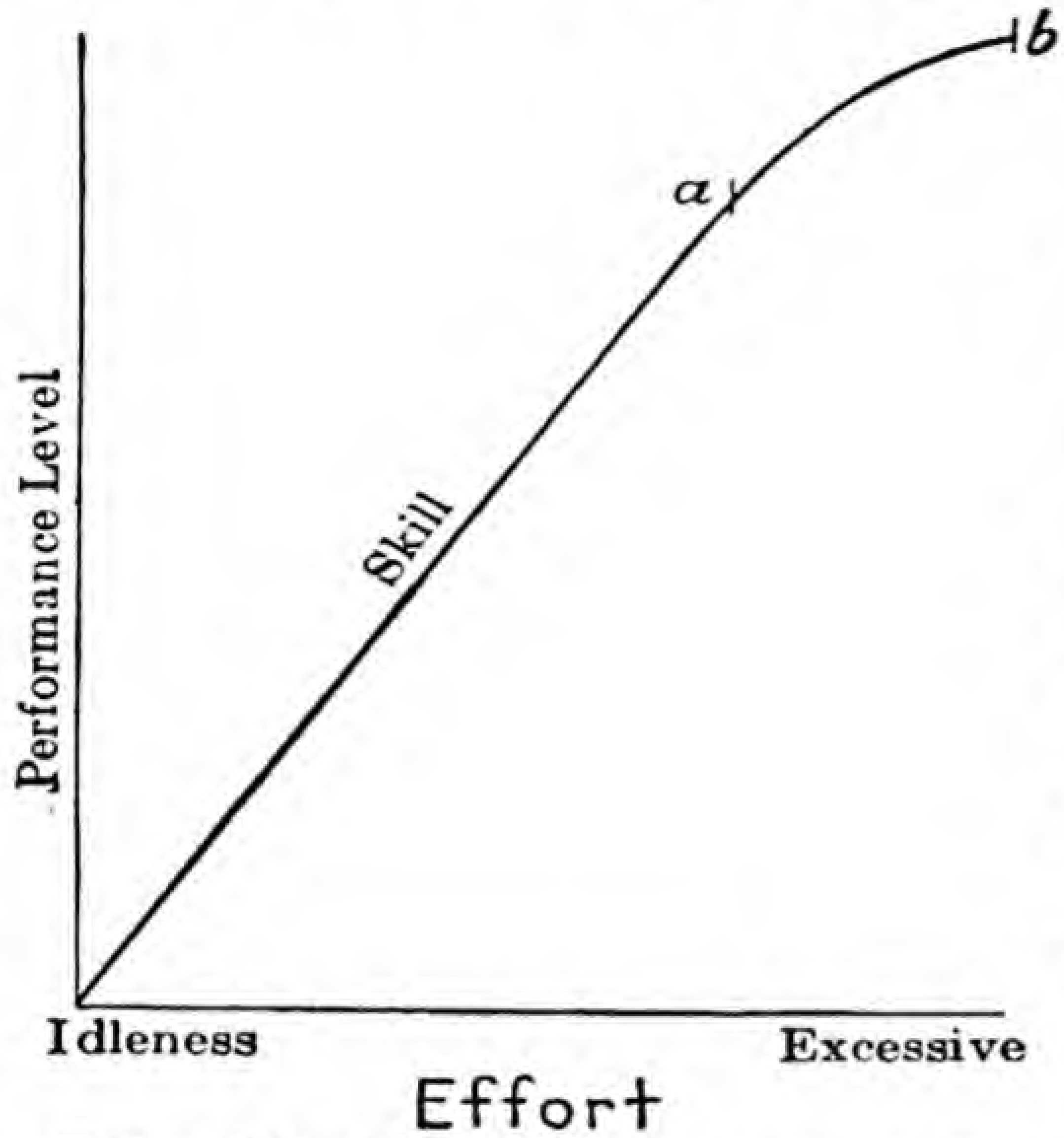


FIG. 109.—Curve showing variation of performance level over complete range of effort for a given degree of skill.

Performance-rating Factors. When the performance-rating factors are first examined quantitatively, the range which they cover seems rather small. One recalls reported cases where one man was able to turn out three or four times as much work as another, whereas the leveling factors allow only for a difference between the best and the worst in the proportion of two to one. Whenever cases of this kind are observed firsthand, however, it is invariably found that other factors besides skill and effort enter in. In practically every case, differences in method are found, and the high producer is using the better method. The differences in method are overlooked by the untrained observer, and he attributes all of the difference in output to a vague something which he calls skill.

Where identical methods are used—and this usually prevails only where detailed motion study work has been done accompanied by intensive operator training—differences in output are slight. Even where different operators use different methods, it is seldom that any one operator has a better method in every respect than every other operator. Usually, one operator has a superior method for, say, the first part of the operation, another for the middle part, and still another for the last part. These differences tend to balance one another and keep output relatively the same even where intensive methods work has not been done. Time studies taken on the various operators and leveled in accordance with the method described above will, therefore,

very often give the same final time allowances within practical limits, although an element-by-element comparison will show discrepancies which can only be explained after detailed motion study.

It is not difficult to correlate the range of the Performance-rating Table with the range of individual differences found by the industrial psychologist, if the whole situation is understood. The psychologist tests groups of people from the whole population and in general finds that the results fall along the normal curve of distribution, as in Fig. 110.

The industrial organization, however, employs only a portion of the entire group. This portion is chosen for marked ability to perform the work at hand, as the result of the work of the

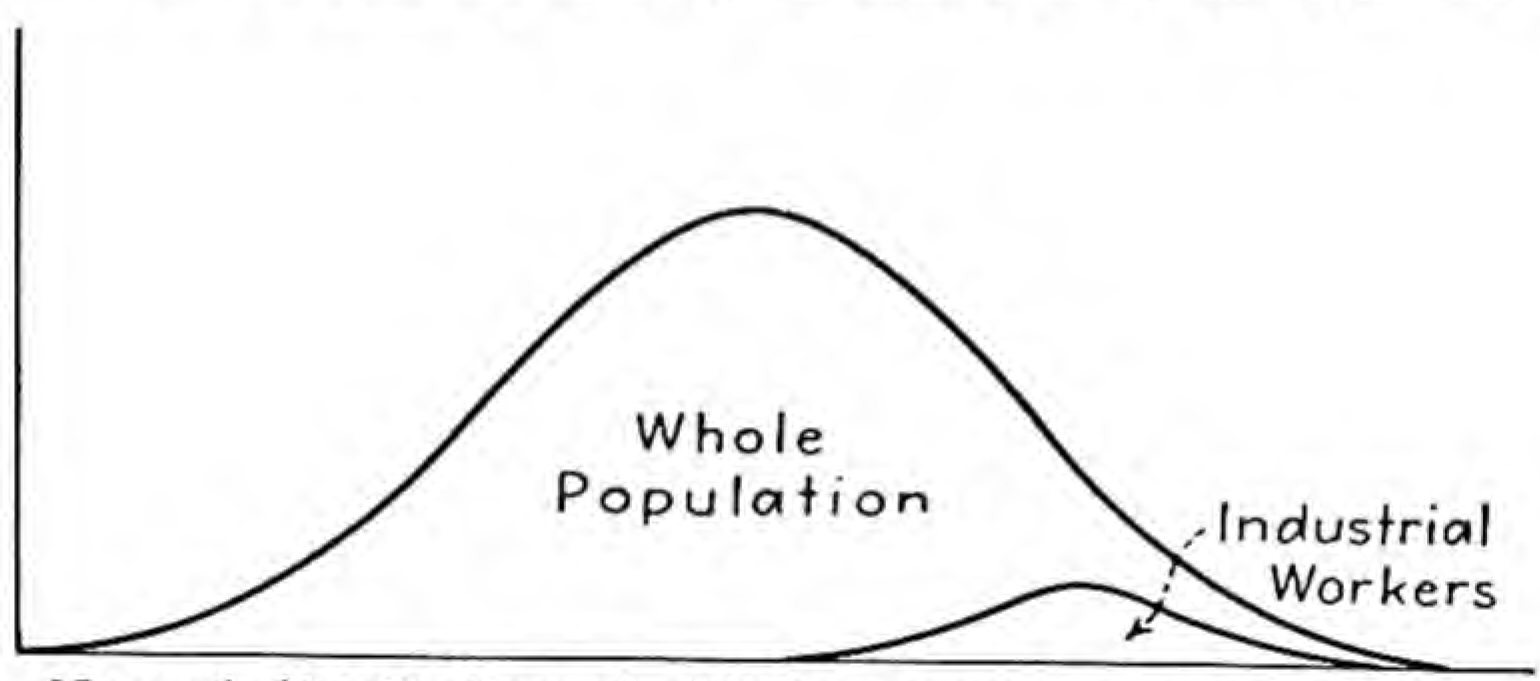


FIG. 110.—Normal distribution of abilities among an unselected group of the whole population and among industrial workers.

employment department and the natural selective processes which are constantly going on. Therefore, only those individuals from the original group whose abilities place them within the curve marked Industrial Workers, Fig. 110, are taken into industrial organizations. The range for this curve corresponds to the range of the Performance-rating Table. It is recognized as a possibility that there may be some super-super-experts who fall above the highest classification in the book. They may exist, theoretically at least, but the authors have never encountered them. Invariably, the super-super-man turns out to be only the good man using a superior method. It is realized, however, that no three men can hope to observe all industrial workers, and therefore the possibility of the existence of super-super-individuals is recognized, pending confirming evidence one way or the other.

The original performance-rating figures were compiled from the results of the time studies taken by about 175 men who made

comparison studies whenever they could over a period of about one year. Since the figures were first published in 1927, they have been checked independently by several industrial organizations without any important discrepancies being discovered. Properly applied, with an understanding of the principles upon which they are based, they will be found to give satisfactory results. It must be clearly understood, however, that the leveling process cannot be used to adjust for differences in method.

Number of Pieces Studied.—The greater the number of pieces studied, the greater will be the number of elapsed-time readings obtained for each element and hence the more truly representative will be the average elapsed-time value obtained. Thus, in every case, it is desirable to study as many pieces as possible.

An actual time study on core making gave the following elapsed-time values for the element of "rap core box," for 16 pieces:

0.0020	0.0013	0.0014	0.0012
0.0014	0.0020	0.0014	0.0019
0.0014	0.0020	0.0015	0.0012
0.0011	0.0020	0.0018	0.0011

If only one piece had been studied, the elapsed-time value would have been the first, or 0.0020. If five had been studied, the average elapsed time value would have been 0.00144. If 10 pieces had been studied, the average value would have been 0.00156. Actually, on the 16 pieces studied, the average elapsed time value was 0.00152. It is readily seen that the first value does not happen to be representative. The first five values give a better value, but there are still too few readings to justify absolute confidence in the accuracy of the average value. Ten readings give a truly representative value which is changed only very slightly by the study of six more pieces. In fact, the change is hardly great enough to warrant the extra time and work involved in securing the additional data. This bears out what was said under Observations concerning the influence of the law of diminishing returns on the number of pieces studied.

Variations in individual observed times for a given element may be due to several factors. The condition of the material may vary from piece to piece. The fact that material is usually jumbled about in a container means that the operator cannot always get it in exactly the same way, and this causes minor variations in the methods employed. Similarly, other slight

variations such as in the position of the tool, the amount of material used such as core sand, and the like will cause variations in the motions used. In addition, the operator may not always maintain the exact performance level from piece to piece. Finally, the mere fact that the stop watch is read to only the nearest 0.0001 hour is in itself sufficient to cause variations in time data.

If the level has been accurately determined, the total standard time as determined from a study on one piece should not differ greatly from that obtained from a study on 10 pieces. The elemental standard time values will vary, however, for while some

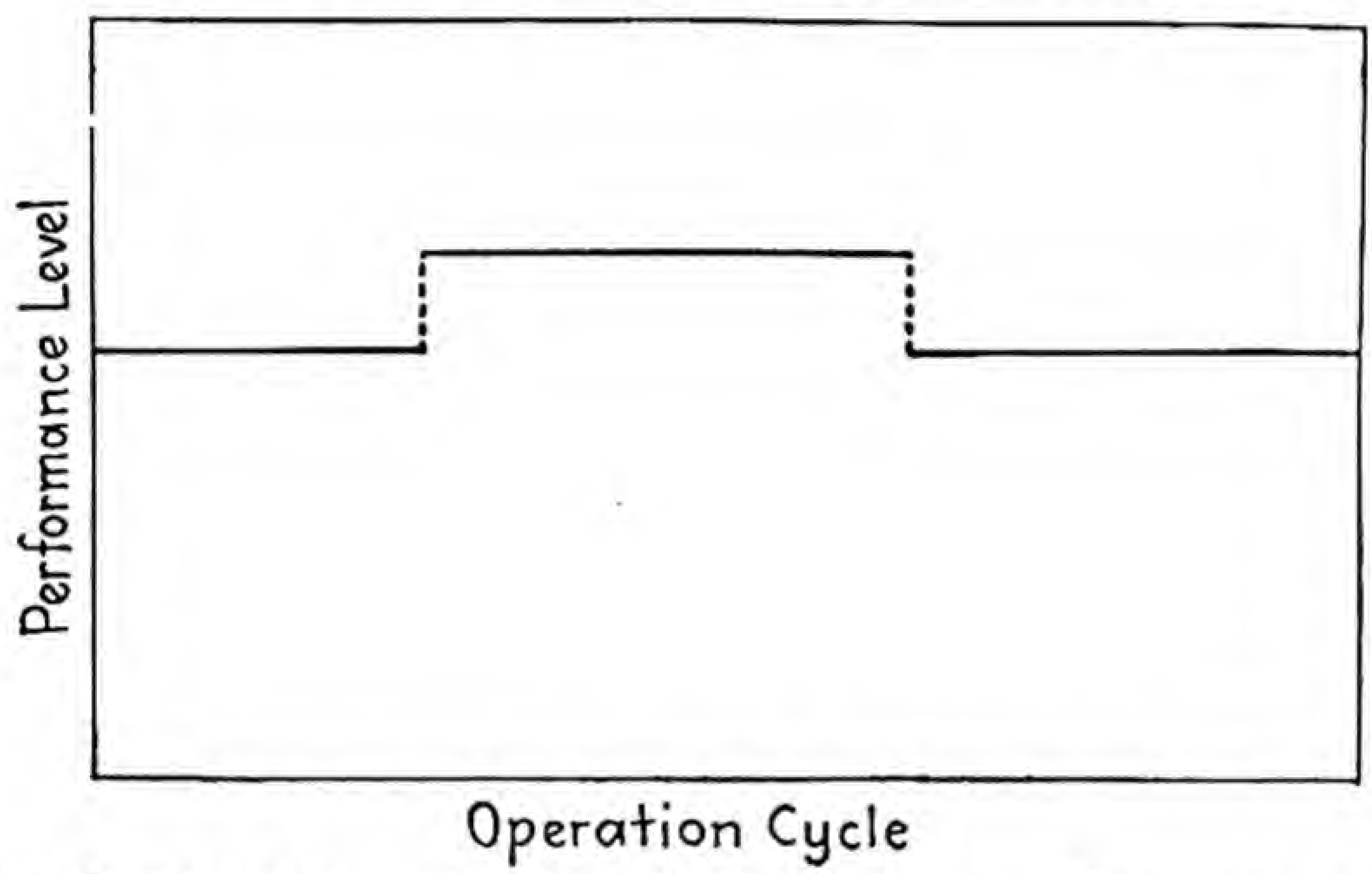


FIG. 111.—Graphical representation of variation in performance level during operation cycle.

are close to what would be obtained from averaging 10 pieces, others are higher or lower. It is important that all elemental time values should be truly representative if the study is to be used later for formula construction.

The leveling method makes it possible to take skill, effort, and conditions into account when the study is made on only one piece. Thus, if there is only one piece available for study or if the time-study man is exceedingly pressed for time, it is possible to get a usable study from one piece. Because, however, of the variation in elemental-time values just mentioned and because of the difficulty of determining accurately at just what level the operator is working during the short time when the study is being made, it is recommended that the practice of studying only one piece be avoided whenever possible.

Variations in Level during One Operation.—An operator may not always work at the same level throughout the entire time study, particularly if the operation is long. If the study lasts all day, the man may slow up during the afternoon because of fatigue. It may be that on a comparatively new job, an operator shows only average skill during the first and the last parts of the operation, but during the middle part, because it is similar to an operation he has performed many times before, he shows good skill. In this case, his performance level during the whole operation will be as shown in Fig. 111.

Wherever there is a change in level due to any condition, the time-study man should note it at the time and the operation affected by it. Later when he is working up his time study, he can change his percentage-leveling factor as is necessary. In some cases, it may even be necessary to rate each element of the study separately. The leveling procedure is flexible enough to take care of cases of this kind.

CHAPTER XX

ALLOWANCES

An allowance is extra time which is added to the leveled time to care for various items which require the operator's time and which are not a regular part of any one job. The determining and making of correct allowances is a very important step in time-study work. The time-study man will be called upon by the supervisory force as well as by the operators to answer questions as to how this or that thing is taken care of. In order that he may be in a position to answer such questions intelligently, he must make a thorough study of the conditions surrounding the job to determine the kind and amount of allowances he must make.

When the time study is taken, time for performing all foreign operations is deducted. The workers often question the justice of this since they realize that some of the delays, although not strictly a part of the job, are entirely unavoidable. The time-study man should be able to explain clearly that the purpose of the study is to determine the correct time for the performance of the job, exclusive of everything that is not a regular element of the operation, and that all necessary and unavoidable delays are considered in allowances which are added to the leveled time to arrive at the allowed time. Sometimes it is well to go into detail and explain how allowance percentages are determined, and, in addition, to show the amount of allowance which is made for each delaying factor.

Necessity for Allowances.—The necessity for making allowances should be apparent from the fact that it is not practicable to allow time on individual jobs for human delays, minor breakdowns, and other irregularities which cannot be foreseen. Even if it were possible to do so, it would not be desirable, as it is better to distribute in equal proportion such time to every job or operation performed.

An operator cannot be expected to work steadily all day without delays from some cause, even if his physical condition were such that he could maintain a good effort of performance

all day long, day in and day out, without affecting his health. Human requirements, minor breakdowns, and other irregularities which cannot be foreseen would interfere. The situation of a worker in industry may be compared with that of a man making his first long journey by automobile. He may plan to motor from Pittsburgh to Chicago, a distance of approximately 500 miles. In trying to determine how long it will take to cover the distance, he reasons that, if he holds a speed of 50 miles per hour, he should make the trip in 500 ÷ 50, or approximately 10 hours. Theoretically, this is correct, but after the trip is completed, the motorist finds that it has taken 14 hours. In trying to discover where he lost the time, he reviews the journey from the beginning and recalls several necessary stops he had to make for various reasons. He decides that in the future, when planning a trip, he will have to make allowances for necessary and unavoidable delays. So it is with workers. An operator, experienced on a certain operation and giving a good effort, will find that he performs the operation in 10 minutes. If he works an 8-hour day, he should complete (8 × 60) ÷ 10, or 48 pieces. At the end of the day, however, he always finds that he is a certain percentage short of this amount, and upon reflection reasons that this cannot be avoided, for there are several things that interfere with his constant performance which cannot be eliminated. This condition makes it necessary to study and determine just how much must be added to the leveled time to allow for time lost due to necessary and unavoidable delays. The making of correct and accurate allowances is just as important as the determining of the correct leveled time, for it is evident that, if a value which is correct is added to one that is incorrect, the result will be incorrect, and the resultant wrong time values will destroy the confidence and cooperation of the workers. Allowances are usually divided into four classes: personal, fatigue, unavoidable delays, and special.

Personal Allowances.—The first question of allowance to claim the attention of the time-study man is the allowance for personal requirements. The items which come under this class are few in number, and the amount of time used for this purpose varies with the person rather than with the conditions of the work. Thus the amount of time required by the average normal person should be determined and added to the standard time in the form of a constant percentage.

Fatigue Allowances.—The items which are classed as fatigue vary in number and amount according to the working conditions, job conditions, and the length of the operation. The question of fatigue has caused considerable discussion, and there have been various theories and ideas advanced concerning ways of counter-acting the effect of fatigue on the worker. Extensive experiments have been conducted to determine the effect that rest periods have on fatigue. Some very interesting results have been obtained from these experiments, but the results and claims are not consistent. This inconsistency is believed to be due to the human element. It is believed that a fair fatigue allowance should be determined and added to each job to be used at the discretion of the operator. Then those whose physical condition is such that they can work more steadily than others will get the benefit of the added effort in the form of increased earnings. This is fair to those who require rest periods as well as to those who do not, for physical capacity is one measure of ability and worth. There are some classes of work for which only the physically strong are fitted, and even the strongest can work only a comparatively small part of the time. The time-study man must determine the particular conditions surrounding each job and make allowances for them accordingly.

Unavoidable Delays.—Unavoidable delays are delays which occur in spite of the efforts of the operator to prevent them. They are delays which are out of the control of the operator and may occur to the good as well as to the poor operator. It is true, of course, that a good operator with greater experience will have fewer delays than a poor operator, but this is because of his better knowledge of conditions, acquired over a number of years, which permit him to plan ahead. The better man will gain in proportion to the amount by which he reduces delays, which is but just.

The unavoidable delays which may occur on a given class of work depend on the nature of the work and the conditions surrounding it. Where a machine is set up by a special set-up man, the operator may have to wait for a few minutes until the set-up is completed. If the time is long, he should be allowed to stamp an extra day-work time slip to cover the time spent in waiting. Where it is comparatively short, it will not pay him to make the necessary trips to the office, but he will lose the waiting time just the same. The delay allowance must cover this lost time. It

must also cover such small delays as those caused by an occasional hard or warped casting, the breakage of tools such as drills and taps, time spent on making minor repairs on patterns or core boxes, interruptions by foreman, production man, or engineers, delays at toolroom or storerooms, time lost working on castings which are discovered to have blow holes after partial machining where the quantity is not great, and other similar small unavoidable delays.

It is always best to have as nearly ideal conditions as possible, and the time-study man should do all he can to insure this. Often such conditions do not exist, for the work may be of such a variable nature that to maintain conditions which would be considered ideal for all cases would be so expensive as to be prohibitive. In any event, the conditions should be as good as is practicable, the element of expense being taken into account. After the time-study man has determined what conditions should exist and has done what he can to bring them about, he should make a thorough analysis and study to determine every point where a loss of time may occur which would not be the fault of the operator. Thus he will arrive at the correct allowance to make for unavoidable delays.

Special Allowances.—Within a given class of work, there may be certain jobs on which delays or fatigue are much greater than is usually the case. The ordinary allowances for fatigue and delays will not be great enough to cover these jobs. For instance, a blacksmith may have a few jobs on which the flow of work is practically steady and he will have no time between heats to rest. Here fatigue is greater than that covered by the usual allowance, and an additional special allowance must be made.

Again, consider a man winding insulating tape on copper coils. These coils are ordinarily light enough to allow the operator to handle them by himself. Certain large sizes, however, are too large for him to handle alone, and he needs another man to help him. He may experience an unusual delay in waiting for a laborer to come and help him, and a special allowance must be made on these particularly large jobs to cover time so lost.

Certain materials require special allowances. A machine operator may have a greater amount of scrap when machining a particularly brittle material than he would ordinarily experience. For example, a milling-machine operator would not expect any scrap due to breaking or cracking of material when milling cast

iron or brass if he were using the proper speeds and feeds. When, however, he is working on an order of soapstone parts, he will have a certain amount of scrap due to the chipping of the edges even though he is using the speed and feed which have been established as best for doing the work. Here a special allowance must be added for milling jobs made out of this material.

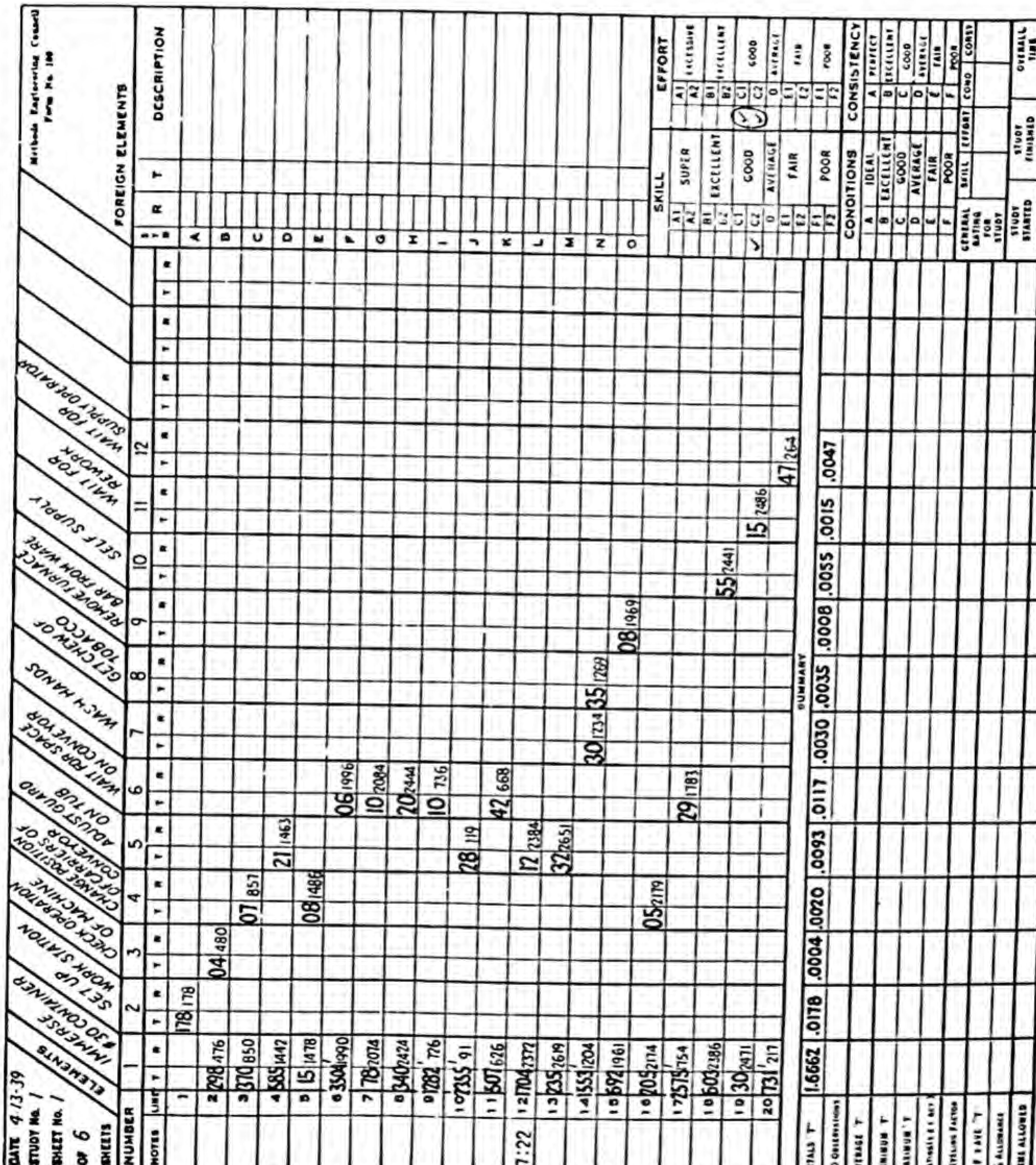
These few examples will suffice to show under what general conditions special allowances are required.

Determination of Allowances.—The kind and the amount of allowances to be made should not be estimated or decided in an arbitrary manner, but should be the result of thorough analysis and careful study. A number of individual workers are studied for a week or two, or even longer, depending on the variableness of the class of work. When the study is being taken, the overall time for each piece is noted as such, and all delays are listed in the columns for foreign elements. If the overall time is long, more foreign elements may occur than space is provided for on the time-study form. When the columns for foreign elements are filled, several columns in the body of the time-study form may be roughly blocked off in pencil and used for noting additional foreign elements. Such time studies should extend continuously over a full working day, and a careful watch should be kept of every move made by the operator.

Where the operation cycle is short, as in the case of a punch-press operation, the recording of the overall time for each piece and the subsequent working up of the data require more labor than the detailed information gained from this method of recording data will justify. When making all-day studies on this type of work, it is more satisfactory to arrange the data as shown in Figs. 112 and 113. In the first column of each sheet, working time is recorded. The remaining columns are used for recording the various foreign operations which occur. If a given foreign element is repeated a number of times, this arrangement of data conserves considerable space. In Fig. 112, a total of 21 foreign elements occurred. Had the horizontal lines under "Foreign elements" been used, 21 lines would have been needed, requiring 2 forms or special ruling as described above. Using the arrangement shown in Fig. 112, the observations were all recorded under 11 column headings. In order to gain a rough idea of performance as the day progresses, the time of day is noted hourly on the proper line in the column headed, "Notes." The total

number of pieces completed hourly and for the entire day should also be recorded.

After the time study has been completed, the delays should be classified as personal, unavoidable, special, and unnecessary. Unnecessary delays or delays which may be purposely introduced



Methods Engineering Council Form No. 100

DATE 4-13-39 STUDY No. 1 SHEET No. 1 OF 6 SHEETS

NOTES	LINE	1 IMMERSE #30 CONTAINER (T / R)	2 SET UP WORK STATION	3 CHECK OPERATION OF MACHINE	4 CHANGE POSITION OF CARRIERS OF CONVEYOR	5 ADJUST GUARD ON TUB	6 WAIT FOR SPACE ON CONVEYOR	7 WASH HANDS	8 GET CHEW OF TOBACCO	9 REMOVE FURNACE BAR FROM WARE	10 SELF SUPPLY	11 WAIT FOR REWORK	12 WAIT FOR SUPPLY OPERATOR
	1		178 178										
	2	298 476		04 480									
	3	370 850			07 857								
	4	585 1442				21 1463							
	5	15 1478			08 1486								
	6	3504 1990					06 1996						
	7	78 2074					10 2084						
	8	340 2424					20 2444						
	9	1282 726					10 736						
	10	7355 91				28 119							
	11	507 626					42 668						
7:22	12	1704 2372				12 2384							
	13	235 2619				32 2651							
	14	1553 1204						30 1234	35 1269				
	15	692 1961								08 1969			
	16	205 2174			05 2179								
	17	2575 1754					29 1783						
	18	603 2386									55 2441		
	19	30 2471										15 2486	
	20	731 217											47 264
TOTALS "T"		1.6662	.0178	.0004	.0020	.0093	.0117	.0030	.0035	.0008	.0055	.0015	.0047

SUMMARY: NO. OBSERVATIONS; AVERAGE "T"; MINIMUM "T"; MAXIMUM "T"; RATINGS S E C AVE; LEVELING FACTOR; L F x AVE "T"; % ALLOWANCE; TIME ALLOWED

FOREIGN ELEMENTS: SYM. A–O; R; T; DESCRIPTION

SKILL: A1 A2 SUPER; B1 B2 EXCELLENT; C1 C2 GOOD ✓ (C2); D AVERAGE; E1 E2 FAIR; F1 F2 POOR

EFFORT: A1 A2 EXCESSIVE; B1 B2 EXCELLENT; C1 C2 GOOD (circled); D AVERAGE; E1 E2 FAIR; F1 F2 POOR

CONDITIONS: A IDEAL; B EXCELLENT; C GOOD; D AVERAGE; E FAIR; F POOR

CONSISTENCY: A PERFECT; B EXCELLENT; C GOOD; D AVERAGE; E FAIR; F POOR

GENERAL RATING FOR STUDY: SKILL; EFFORT; COND; CONST

STUDY STARTED 6:22 A.M. STUDY FINISHED 1:51½ P.M. OVERALL TIME 7.5916 HRS

FIG. 112.—First page of all-day time study taken for allowance-determination purposes.

by the operator should not be considered when establishing allowances, and the time thus consumed should be subtracted from the length of the working day. The time lost due to the other delays should be totaled and the percentage thus lost computed by dividing time lost by the total legitimate working

time on productive operations. After delay percentages have been found from several all-day studies on different operators, the results should be averaged. The percentages thus determined may be established as the allowance percentages for delays

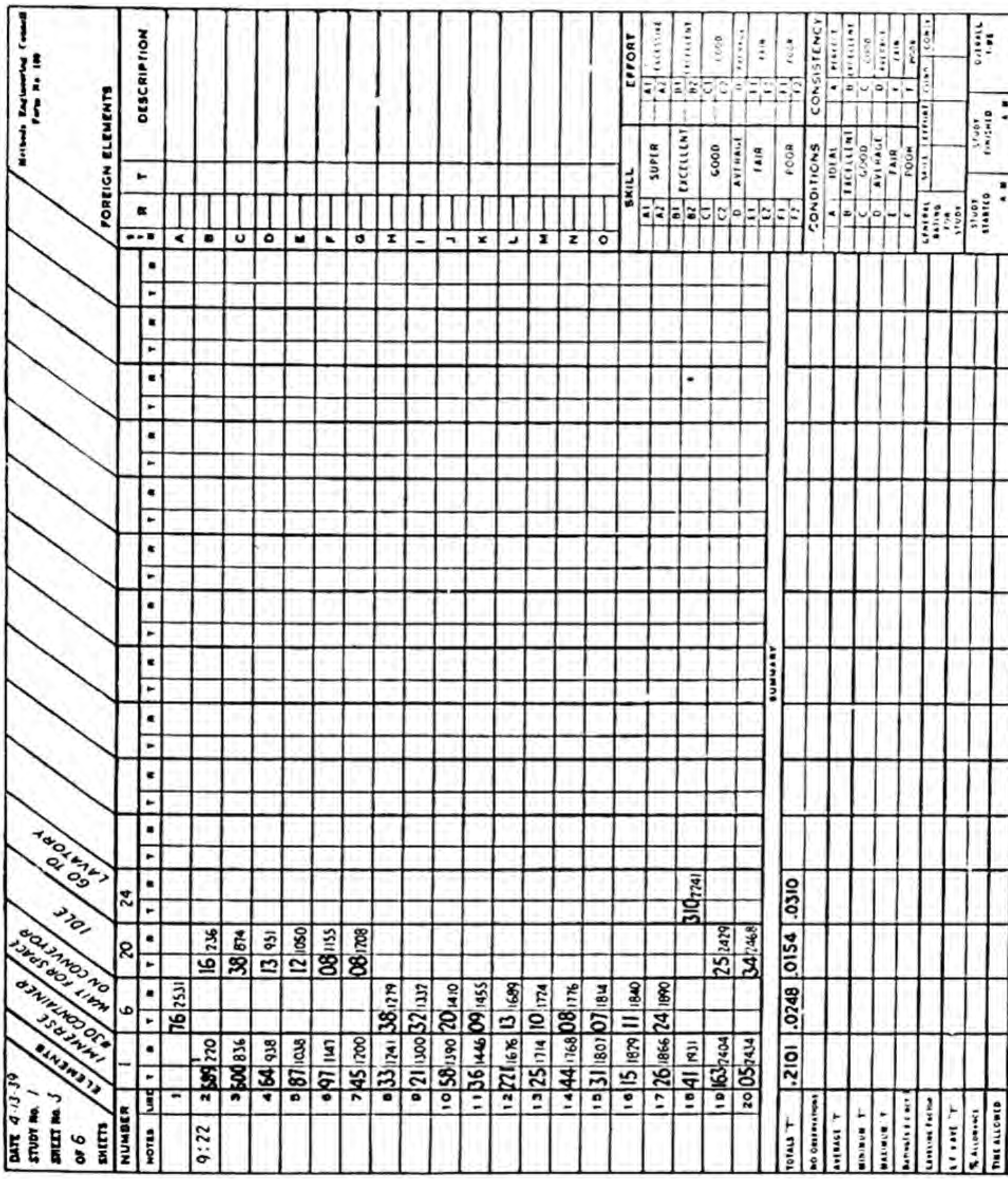


FIG. 113.—Third page of all-day time study taken for allowance-determination purposes.

within the particular class of work on which the studies were made.

The percentage to be allowed to care for fatigue may be found from these same studies. When the studies are taken, the skill of the operator and the effort exerted during the first part of the day should be noted. When the study is worked up, the overall

productive time for each piece may be found by deducting the time spent on foreign elements while the piece was being made from the overall time for that piece. The standard time for doing this particular operation should be established by a detailed time study. Now, if the operator observed on the all-day study has been properly rated as to skill and effort at the beginning of the day, the net overall times for doing the job at the beginning of the day after being leveled should correspond closely to the leveled time established by detailed time study. That is, when a man for whom a leveling factor of 1.10 has been determined is working on a job having a leveled time of 0.075 hour, it will be found that his net overall time for each piece at the beginning of the day will range within a few per cent plus or minus of 0.075/1.10 or 0.0682 hour. Expressing this algebraically,

$$\frac{S}{L} = T,$$

or

$$TL = S,$$

where L = leveling factor,
S = leveled time per piece,
T = net overall time per piece.

As the day progresses, the worker will begin to feel the effects of fatigue. His net overall times will start to increase because fatigue is slowing him up. If a detailed time study were being taken on him, he would receive a lower effort rating than he did in the morning. If, however, the leveling factor is not changed, the above equation will no longer hold true but will become

$$TL - d = S,$$

where d is the amount of time the man is actually slowed up by fatigue.

Theoretically, at least, the time lost due to fatigue will be an ever-increasing amount as the day progresses, unless rest periods or change of work lessen the effects of fatigue. The total amount of time D thus lost during the day may be found from the sum of net overall times O and the number of pieces worked N from the equation.

$$OL - D = NS,$$

or

$$D = OL - NS.$$

The amount of time lost due to fatigue expressed in per cent may be found from the equation

$$\left(\frac{OL - NS}{NS}\right)100 = \text{per cent fatigue factor,}$$

or

$$\left(\frac{OL}{NS} - 1\right)100 = \text{per cent fatigue factor.}$$

To illustrate this, the following shows how the all-day study on immersing No. 30 containers in enamel, shown in part by Figs. 112 and 113, would be worked up.

The final watch reading of the study was 7.5954. After subtractions were made and computations completed, this time was found to have been occupied as follows:

Working time—immersing No. 30 containers	6.3850
Personal delays	0.3416
Unavoidable delays	0.2560
Avoidable delays	0.1907
Lunch	0.4221
Total	7.5954

The allowances for personal and unavoidable delays are computed as follows:

Personal delays: $\left(\frac{0.3416}{6.3850}\right)100 = 5.4$ per cent

Unavoidable delays: $\left(\frac{0.2560}{6.3850}\right)100 = 4.0$ per cent.

No allowance is made for avoidable delays.

The total number of pieces completed during the course of the study was 1,972. The skill and effort rating given the operator during the first hour of the day was *C*2 skill and *C* effort. The allowance for fatigue may be found from these data by substituting in the equation:

$$\left(\frac{OL}{NS} - 1\right)100,$$

or

$$\left(\frac{6.385 \times 1.065}{1{,}972 \times 0.0033} - 1\right)100 = 4.6 \text{ per cent.}$$

The total allowance as determined by the all-day study is 5.4 per cent + 4.0 per cent + 4.6 per cent or 14 per cent. If it is felt that this study covered representative conditions, a 14 per cent allowance would then be used on this and all similar operations to allow for time lost because of fatigue and personal and unavoidable delays.

CHAPTER XXI

ALLOWED TIME

After the time study has been worked up and the elemental leveled times determined, and after a proper percentage allowance for existing conditions has been definitely established, it is necessary to determine the actual time value which will be given for doing the job. This time value is called the allowed time. It must include not only the time for performing the repetitive elements of the operation but also it must include the time for doing the non-repetitive or so-called set-up elements. In short, time must be allowed for every necessary operation performed in turning out a complete job on a number of pieces. There are several ways of handling this allowed time, and a brief discussion of the relative merits of each is given in the succeeding paragraphs.

Determination of Set-up Time.—There are certain operations which are not repeated for every piece but which must be performed if the job is to be done. These operations occur at the beginning and ending of a job and are known as the set-up operations.

In determining the set-up time, the time-study man will study all the elements that occur while making the set-up and record the time for doing them. The same care and attention should be exercised in studying a set-up as when studying the operation to follow. This is especially true where the time allowed for the set-up is likely to be a large percentage of the total time allowed on a given job, for then, if the time-study man has been liberal by neglecting to take out foreign operations, the result will be the same as though he had been careless on the entire job and had established values which were too high. On the other hand, if he had been careless by neglecting to consider some of the essentials in the set-up, the result would be the same as though he had established values which were too low on the entire job. The set-up includes such items as getting the job from the foreman or dispatch clerk, getting all information necessary such as drawings

and other specifications, studying the specifications to determine the job requirements and the tools needed, getting the tools from the tool room, and if necessary, properly grinding them, setting and adjusting tools and stops if a machine job, or making the preparatory set-up and adjustments of tools and equipment if a bench job, and making a trial piece or trial layout and having it approved by inspector and foreman. The foregoing operations usually occur at the beginning of a job. Still other operations which are considered as being part of the set-up occur at the ending of a job, for example, removing all special equipment that has been set up for the job just finished, returning this to the tool room, cleaning the machine or work station preparatory to starting the next job, making out a time card, and shipping the job just completed.

After the time for each elemental operation of the above nature, exclusive of all foreign operations, has been carefully determined, the individual times are totaled. The result is established as the set-up time for the operation under consideration and is recorded as such to be allowed each time the job is worked.

Determination of Time for Each Piece.—In the each-piece time should be included the total time necessary for doing all of the necessary repetitive elements of the operation, that is, all of the elements which are repeated each time the operation is performed. This is simply the sum of all of the elemental standard times for every element of one complete cycle of the operation, together with the proper allowances. The elemental standard times were determined from the time study taken on the operation. The percentage allowance was determined for the particular class of work by a series of studies extending over a number of full working days. The elemental allowed times were found by increasing the elemental standard times by the proper per cent allowance. Finally, the allowed time for each piece will be the sum of these elemental allowed times, each element being multiplied by the number of times it occurs in one cycle.

Distribution of Set-up Time over Manufacturing Quantities.—This method of handling allowed time is rather crude and is not very accurate, but it is at least workable. The manufacturing quantity in which the job is likely to be put through the shop is determined by past records or is merely estimated. Then the

time required for set-up operations is divided by the number of pieces in the job lot to determine how much of the set-up time shall be apportioned to each piece. This time is added to the each-piece time, and the result is the allowed time for each piece for doing the operation.

If the job always comes through in the predetermined quantities, this method will give an accurate time value for the job. This is, however, seldom the case. An unforeseen large order will give the worker an advantage, for the set-up time will be distributed over a greater number of pieces. If the job occurs in smaller quantities, the worker will be correspondingly penalized. If a shortage occurs due to defective material or workmanship, the worker may have to make a complete set-up for only one or two pieces. Obviously, in this case, he will fail to meet the allowed time by a large amount. Costs as determined from these allowed times will not be accurate if the manufacturing quantities vary. They will, however, be easy to compute since only one time value must be considered.

In order to overcome the chief objection to this method, that of inaccuracy when the manufacturing quantities vary, sometimes several allowed times are established depending on the number of pieces on order. The allowed time per piece will be a certain amount on lots up to 10 pieces. Between 10 and 20 pieces it will be another value slightly less than the first and so on. The accuracy of this method depends on how finely the divisions are made. In determining the cost of doing the job, the actual cost is more closely approached. The cost system, on the other hand, is more complicated, paper work is greatly increased, and record files are more cumbersome.

The Set-up as a Separate Allowed Time.—Often, the set-up is an entirely separate operation, that is, the set-up is made without actually completing any work, or again, the set-up is made by an entirely different operator from the one who uses the set-up to do the job. The reasons for this latter condition are several. It may be that the class of operator required to make the set-up is high, while the class of operator required to use it is comparatively low. In a case of this kind, it is readily seen that it would be considerably cheaper to have set-up men to take care of the setting up of a group of machines. The same thing is true of work other than machine work. For example, in making large transformers, one of the operations is known as "building."

Preparatory to building, it is necessary to set up the job, which consists of blocking up the base and setting up the frame, coils, and insulation. This work is done by a group of men who are specialists in this line. Thus there are always set-ups ahead of the other lower-grade men who go from one set-up to another to build up the iron laminations. Another advantage derived from having set-up men is continuous performance or elimination of lost time. This is accomplished by having extra machines always set up so that when an operator finishes a job on one machine, he moves over to another machine to do the next job which is already set up. It is, of course, to be understood that the conditions will warrant the investment in the additional machines. In any of the above or similar cases, it is desirable and proper to establish the set-up time as a separate allowance and record it accordingly.

Partial Set-ups.—By a partial set-up is meant a set-up where all set-up operations do not have to be performed, because due to similarity of jobs, part of the set-up already made need not be disturbed. For example, one of the tools used in making a part on a J. & L. turret lathe may be used without adjustment on the next job. As a result, only five tools need to be set up. In such a case, should the set-up man be paid for setting up only five tools or should he be allowed time for setting the entire six?

At first glance, it might seem that the operator should be paid only for what he does. If he needs to set but five of six tools necessary for doing a certain job, he should be paid for setting five. Theoretically, this is as it should be, but there are several other practical considerations involved.

Where set-up time is short and where a large variety of comparatively short orders is worked daily, it is exceedingly hard to give partial set-ups. It is not generally possible to have the foreman or the time-study man check every set-up, and it is generally necessary to rely on the honesty of the set-up man or of the machine operator himself for information regarding set-ups. Men who are absolutely honest with each other outside the shop seem to regard a large company in a different light, and it is often very hard to make them feel that they are doing wrong when they turn in time undetected for something they have not done. It is safe to say that the majority of operators will not be conscientious about reporting partial set-ups. If they do not report them, they will get paid for full set-ups. They know that they

are "putting something over" on the company, and the psychological effect is bad. They are likely to exceed bounds in other directions, if they are given a little leeway in one.

Supervision by responsible persons is generally out of the question, because the additional expense involved is not offset by the savings made.

Another factor that is very important is that when set-ups are controlled, there is no incentive for the operators to plan their work to the best advantage. Since they get paid only for what they do, they do not care whether they make all complete set-ups or not. On the other hand, if they are allowed complete set-ups on all jobs, they will plan so that every minute that it is possible to save on set-ups is saved. Thus production is increased.

With the above considerations in mind, it seems best on work where set-ups are short and the time which may be saved small to allow complete set-ups on all jobs. Supervisory expense is reduced, overhead is reduced for this reason and because production is increased, and the psychological effect on the workers is better.

Where set-ups amount to considerable time, it generally takes longer to complete the jobs themselves. It is easier for the supervisors in the department to keep track of the various jobs and note when only partial set-ups are necessary. In this case, it will pay to control set-ups.

Whether or not it will pay to control the set-ups on a given line of work may be determined by the time-study department with the above considerations taken into account.

First-piece and Additional-piece Time.—Under this method, a certain time value is allowed for doing the first piece and another for doing each additional piece. The first-piece time allows time for every operation which would be performed if only one piece were made. It includes the set-up time and the time for performing the repetitive operations for one complete cycle.

The repetitive operations performed on the first piece will generally not be done in the same time that the same operations are done on succeeding pieces. The operator will not have had a chance to get into the swing of the work, and he will take more time to do the first piece. On machine work, he will have to check and measure the piece more often than he will after he becomes familiar with the correct positions of his stops and dials. In bench work, certain difficulties will appear which the operator

will subsequently overcome when he has become accustomed to the job. In molding, a molder may not prepare his parting exactly right the first time, causing a breakage of a section of sand and later necessitating extra patching. On the following pieces, he will know exactly how to prepare the parting, no breakage will occur, and the total operation will be performed in less time. So it is in practically every line of work, and hence the sum of the set-up and the additional-piece times will not give a true first-piece time. Instead, the first-piece time is computed by adding to the set-up time the additional-piece time increased by a certain percentage to care for the delays experienced on the first piece. The additional-piece time is, of course, the allowed each-piece time as determined by time study.

This method of handling allowed time gives very accurate costs, since the costs will be based on the time actually spent on the job. The job may be billed at actual cost, or as is more common, in order to avoid constantly changing costs, the additional cost of the first piece is absorbed in the overhead expense, and the cost figured on the additional-piece-time value.

Special Allowed Time.—Very often it is necessary to allow extra time for conditions which were not considered in establishing the standard allowance. A large lot of extra-hard castings may be encountered which will necessitate a lower machine feed and a smaller cutting speed than that which has been established, or an order of castings may be out of shape due to poor molding or warping, causing a loss of time in chucking and handling. Again, a job may be wanted in a hurry and the material out of which the job is to be made is out of stock, thus making it necessary to substitute some other material which will answer the purpose, but which may be harder to machine if a machine job, or harder to file, saw, or bend if a bench job. Extra time must be allowed to take care of such conditions. The amount of extra time should be determined by time study and added to the standard allowance, and given as a special allowed time for that particular order only. Other examples where special allowed times are necessary are where work is performed on a machine which is in need of repair, where proper tools are not available, where existing conditions are not right for a special job, where work is in a state of development, or where a temporary change in design has been made. The examples here given will suffice to show when a special allowed time is warranted. The above

conditions may also be taken care of by having the work done on the straight day-work basis, but it will usually be found more satisfactory to the worker and more economical to the employer to make a special allowance wherever the extra time can be intelligently determined.

Printed in U.S.A.

INSTRUCTION SHEET

Operation *Face, point, turn and thread short end of stud* Sec. *F-1*

Part *Stud for type 214-A control box* Time Study Formula *A.B.S. #3* *10-4-39*

Dwg. *# 285792* Sub. *8*

Mach. Tool *#5 Warner and Swasey turret lathe* Item

L. Spec. Sub.

Special Tools *Pointing tool J4452* Ins. Spec. Sub.

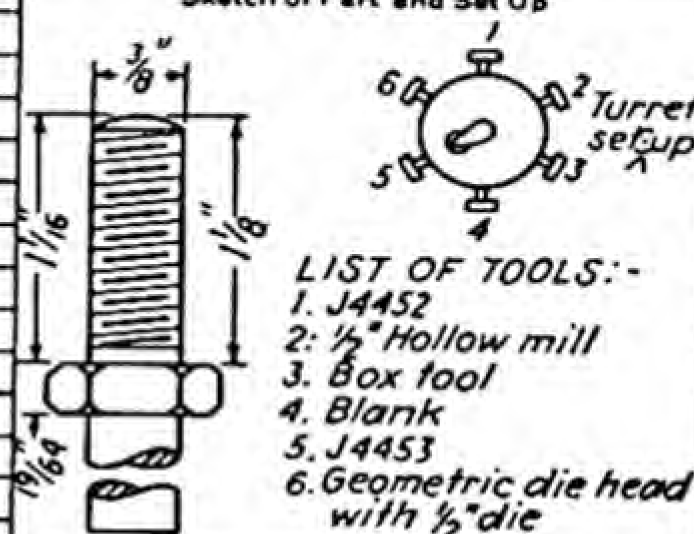
Chamfering tool J4453

Supply *Tools and materials furnished by supply boy under direction of foreman*

Inspection *Must pass thread gage and be free from burrs*

Remarks

Sketch of Part and Set Up



No.	Order of Operations	Form Sym.	Tools	Depth of Cut	Speed RPM	Feed IN/MIN.
1	Get stud from table and place in chuck					
2	Tighten chuck with socket wrench					
3	Start machine					
4	Face stud		J4452	1/8"	274	Hand
5	Turn turret-one position					
6	Point stud		Hollow mill	1/32"	274	Hand
5	Turn turret-one position					
7	Turn stud		Box tool	1/32"	274	430
8	Turn turret-two positions					
9	Chamfer hex		J4453	1/8"	274	Hand
5	Turn turret one position					
10.	Thread stud		Automatic knock-off die	-	274	-
5	Turn turret-one position					
11	Stop machine					
12	Remove stud and place in tote pan					

Date *10-4-39* *A. B. Lea* Rate Man *J. Mason* Foreman Approved *G. M. J.* Time Study Supervisor

FIG. 114.—Instruction sheet for job on which model time study was made.

Choice of Systems.—Individual conditions will determine which of these systems may be applied most advantageously. A shop manufacturing a standard product might use the method of distributing set-up time over manufacturing quantities most conveniently, while the job shop would find the method of first-piece and additional-piece time best suited to its conditions. The point to be borne in mind is that the time spent on set-up

operations must be allowed for when establishing a time value for doing a job. The allowed time, regardless of the method used, must be the standard time for performing the complete operation together with all time allowances for fatigue, delays, and the like.

Instruction Sheet.—When an operation has been thoroughly studied and the best method for doing it has been determined, this method should always be used. The operator may be taught the proper method by the foreman or by a special instructor, or he may be guided by an instruction sheet. An instruction sheet for the operation covered by the model time study is shown in Fig. 114. It gives the detail operations in the order in which they should be performed, and it tells what feeds and speeds to use.

Instruction by the foreman or an instructor is not so exact and consistent as the other method, but it is more practicable. Making instruction sheets and keeping them up to date involves a tremendous amount of clerical work where the nature of the work is at all varied. In plants making a standard product or in processing industries where methods are not changed frequently, instruction sheets are easier to keep up. The very fact, however, that changes are not made frequently enables the operators to learn all of the details of their work by heart, thus defeating the purpose of the instruction sheet.

CHAPTER XXII

STUDYING EXISTING CONDITIONS

The advantages of having working conditions as nearly ideal as possible before making time studies have been fully discussed. but it must not be concluded that poor working conditions, obsolete or inadequate equipment and out-of-date methods are sufficient to prohibit satisfactory results from time-study work. It must be remembered that time study is industry's tool and even though it is sometimes impossible to apply it to the maximum advantage, it will, nevertheless, pay for itself many times over wherever it is introduced for the first time, provided it is in the hands of those who understand it and know how to use it. The last-named provision is especially necessary, for scientific time study has suffered greatly at the hands of novices and self-styled experts. It is just as wrong to put time study into the hands of untrained and incompetent clerks as it is to put a high-grade scientific instrument into the hands of an ordinary laborer and expect good results. In fact, the harm that can result in the first case may be much greater than any that could possibly result in the second. The damage that the laborer can do is probably limited to the value of the instrument and can be measured in dollars and cents, but wrongly applied time study may result not only in a direct and measurable financial loss but also in a detrimental effect upon the morale of the working force and upon the confidence of the management. It is in those places where time study has never been tried that the confidence and support of the management must be secured and maintained. Time study must pay its own way and also leave a comfortable margin of profit in order to justify its existence. In the beginning, then, it is sometimes necessary to show results quickly and not call for large financial outlays for improved equipment or rearrangement of working facilities. If the management is somewhat skeptical of the benefits from the beginning, it is not good policy to increase existing doubts by insisting upon expensive changes, nor is it necessary. In fact, it is in the initial stages of time-study work that the greatest savings can be effected for the money expended. As greater refinements are introduced and manufacturing methods become

more highly organized, the effect of the Law of Diminishing Returns becomes evident, for the increased savings are no longer proportional to the increased cost of maintaining time-study work. It still pays but it does not pay so high a return on the investment as it did at the beginning. There is a theoretical saturation point beyond which further refinements in time-study work are no longer profitable, although it is doubtful if this point has ever been reached as a practical matter on account of the ever-changing conditions in industry. It is, therefore, often necessary to study conditions almost as the time-study man finds them and then by further study revise the original time values as improvements are made by the management.

Wherever labor can be measured and, thanks to time study, it is indeed a rare case that cannot be measured, that labor can be placed on an incentive method of wage payment. There are a number of meritorious systems of wage payment, all of which are based on time study. The primary intent of this book is to explain the methods and uses of time study and not to champion any particular system of wage payment. It is understood, of course, that the economic value of time study can be realized only through the medium of a good system of wage payment. On the other hand, no system of wage payment can long survive that is not founded upon an accurate method for measuring human effort. Analytical time study is the most practicable and feasible means to this end that has so far been developed. Thus it will be seen that the wage-payment system and time study upon which the former is constructed go hand in hand, and the success of each depends to a large extent upon the worthiness of the other. The mistake is sometimes made of overlooking the influence of good time-study work and giving to the wage-payment system too large a share of the credit for savings. The best-known wage-payment system would quickly fall into ill repute if established time values were incorrect and inconsistent. Hence, it is highly desirable to ascertain, when inaugurating time-study work in a plant, first, that it be done by those who thoroughly understand their business, and second, that a good wage-payment system be used in applying it.

Time study has been referred to as a tool. The analogy may be carried further by comparing it specifically to a machine tool, an engine lathe, for instance. The primary function of an engine lathe is to remove metal from raw stock until the piece is brought down to the desired dimensions. This is not done, however, in one operation. First, there are one or more roughing cuts with

heavy feeds that take off the outer scale and irregularities and more closely approach the finish dimensions, say to within $\frac{1}{16}$ inch. Then, perhaps there is a semifinishing cut with a fine feed that brings the dimensions to within $\frac{1}{64}$ inch, and finally the finishing cut. If still greater accuracy is desired, the job will probably be transferred to a grinder. The raw casting may be compared with the plant in which no time-study work or incentive systems have ever been tried. Like the lathe operator who takes the casting as it comes from the foundry and proceeds to set up his machine for the roughing cut, so does the trained time-study man go into the plant and study things just as he finds them. The first roughing cut removes considerable of the excess metal, perhaps over half of it. In like manner can the time-study man establish time values and apply an incentive system of wage payment that will, on the first attempt, with practically no improvement in equipment or conditions, effect an enormous saving in labor costs, perhaps as much as half of the total saving that will ever be possible even after all justifiable improvements have been made. To secure the additional possible saving will doubtless require more than a proportionate increase in effort and expense just as it cost more to remove the second half of the excess metal on the lathe operation; yet the work should be carried on because the theoretical saturation point previously referred to has not been nearly attained. Innumerable examples could be quoted of the enormous savings that have been effected by the initial application of time-study methods and the placing of day-work operations on an incentive system of wage payment. It will suffice for present purposes to give but a few typical examples covering a wide variety of jobs.

Making Reinforced-concrete Slabs.—The product on this job was a flat slab of reinforced concrete about 5 feet long by 2 feet wide by 2 inches thick, to be used for roofing factory buildings. The concrete was mixed and poured into flat molds using cut-steel mesh for reinforcing. A group of laborers were doing the work for a flat hourly rate corresponding to the prevailing rates for that class of work. Before any time studies were made, the production was around 80 slabs daily. Only a short time (1 week) was required to get the necessary time studies and the job was put on an appropriate incentive wage-payment basis. Practically no changes were made in the manner of doing the work and in the equipment used; yet within the amazingly short time of 2 weeks after the incentive wage system was started, production increased to 425 slabs per day with the same crew of

men. Each man's earnings were nearly doubled but this was more than justified by over a 400 per cent increase in production, and more than a 62 per cent decrease in unit labor cost.

Cleaning Castings in Alloy Foundry.—The work of cleaning castings covered such things as knocking out core sand, sand blasting, cutting off sprues, gates, and risers, grinding off fins and other rough surfaces, washing when required, and chipping and filing when necessary. The work was very disagreeable and undesirable, and labor turnover was very high. It was extremely difficult to keep men on the job when labor was scarce. Before the work was analyzed and studied, a crew of 78 men was necessary to keep up with foundry production, which normally was around 600,000 pounds of finished castings per month. In this case some changes were at first recommended by the time-study man, but the management was reluctant to carry out the recommendations and the work was studied without the changes being made. Two months after the time studies were completed and the incentive system started, the work that had required a gang of 78 men was being done by 32 men. Individual earnings were increased 35 per cent but against that was an increase in individual production of 144 per cent and a reduction in the force of 59 per cent. The actual saving in labor cost was equivalent to 35 men or about 45 per cent.

Removing Excess Gum Tape from Armature Coils.—This was another disagreeable job on which the labor problem was always acute. It was somewhat isolated from the other work in the department which made close supervision impossible, and the laborers employed doubtlessly took advantage of this situation. The five men on the job were sometimes unable to keep up with the flow of work. Time study and an incentive system brought about the almost unbelievable results of eliminating four of these five men. The one man who continued to do the work increased his earnings about 67 per cent, but the net saving in labor cost was also about 67 per cent, and individual production was increased 400 per cent.

Storeroom Work.—A group of 14 men were employed in a storeroom. Their work consisted of receiving, storing, and supplying material to workmen in a large manufacturing department. In busy times there was an average of about 90 man-hours a week of overtime at time and one half, which would have been equivalent to 3 extra men or making an equivalent of a group of 17 men working regular hours. These men were not particularly interested in the production on the manufacturing floor.

It was necessary for workmen to go to the storeroom frequently for material, and in general the service was poor. The incentive system that was established after sufficient time studies had been made provided that the earnings of the storeroom attendants should be determined by the volume of finished work produced by the department. This definitely tied the storeroom to the production activities, and the attendants were definitely increasing their own earnings when they helped the producers on the floor to a greater output. The original force equivalent to 17 men in busy times was reduced to 9 men with an average increase in individual earnings of 25 per cent.

Crating Finished Product for Shipment.—Ten rough carpenters were regularly employed on a straight hourly basis on this particular job, which was attended with the usual difficulties of a day-work job where steady flow is required. The work consisted of taking the piece of apparatus from an industrial car as it came from the manufacturing floor, placing it in the crate which had been previously placed on a roller conveyor, blocking the machine inside the crate, nailing on the lid, marking, and stacking preparatory to shipment. After the job was studied and placed on an incentive system of wage payment by a competent time-study man, the number of men in the group was gradually reduced from the original 10 until only 2 of the best men remained. The day-work rate had originally been about 53 cents an hour making a total labor cost of $5.30 an hour. Under the new incentive plan each man earned $1.10 an hour making a total hourly labor cost of $2.20. This was an increase in individual earnings of about 108 per cent, but to offset this their individual production had increased 400 per cent, the total force had been reduced 80 per cent, and a saving of over 58 per cent in labor costs had been effected.

Band-saw Operation.—Three band saws were employed exclusively on sawing asbestos lumber. Three men were employed on day turn and three on night turn, making six men in all working the equivalent of regular day-turn hours. They were paid 53 cents an hour on a day-work basis. Time studies were made and the work was put on an incentive basis of wage payment. Some minor changes, such as changing the speed of the saws, were recommended by the time-study man and adopted, but none of them involved additional expense or delay. Within 3 months two men were doing the work formerly done by the six. The new earnings were 90 cents an hour, an increase of 70 per cent, but

individual production was increased 200 per cent and the cost was reduced over 43 per cent.

Summary of Examples.—In selecting the foregoing examples of quick results from time-study work, it was not only the intent to show what enormous savings are sometimes possible, but also to show the practically unlimited application of time study by taking examples that represent greatly diversified lines of work. The results of these examples are briefly summarized below:

	Increase in production per man, per cent	Reduction in force, per cent	Increase in individual earnings, per cent	Saving in labor cost, per cent
Making concrete slabs	400	0	100	62
Cleaning castings	144	59	35	45
Removing gum tape	400	80	67	67
Storeroom	88	47	25	34
Crating	400	80	108	58
Band saws	200	67	70	43

It should be emphasized that the above production increases were not obtained by "speeding up" the workers to an undue extent, but rather they were secured by first determining what a reasonable accomplishment was on the job, next making sure that conditions were such that this accomplishment could be attained, and finally by securing greater interest and cooperation of the worker by tying up earnings with production. Experience has demonstrated again and again that workers on a day-work basis have little idea of what constitutes a proper day's production. Because payment is by the hour, their interest is centered on the number of hours worked rather than on the amount produced. Consequently, the retarding effect of interruptions, delays, improper working methods, and so on is scarcely noticed and rarely considered as important by the day worker. When his work is placed upon an incentive basis, however, the worker is in effect put into business for himself. His time is his capital, and the manner in which he invests it determines the return he will receive. Consequently, he endeavors to reduce lost time, to improve his methods, and to increase his skill, and as a result of this rather than any undue increase in effort, he increases his production to a marked degree.

CHAPTER XXIII

USING THE TIME STUDY

Preceding chapters have been devoted almost exclusively to explanations and discussions of how reliable time studies are made, and now one might well ask, "How are they used?" or "Of what value are the results?" These questions cannot be fully answered in one brief sentence, but much of the answer is contained in the statement that they make it possible to measure human effort in an equitable and consistent manner. Chief among the numerous advantages of being able to measure human effort accurately are those that accrue from using the results as foundations for incentive methods of wage payment. The employer can purchase labor on the basis of the work accomplished and the employee can sell it for what it is actually worth—he gets paid for what he does. Some of the other applications of time-study results are in the laying out of production schedules, the calculation of past and the prediction of future costs and the determination of equipment capacities when planning for increased production. Regardless of the ways in which time-study results are ultimately used, the methods of making the studies and of determining those results are not materially affected. It is the intent and purpose of this book to show how time studies should be made and not to attempt to limit their application which is actually very wide, although it might appear at times that the authors are thinking only of their application to wage payment. It is in this connection that they have been used most extensively, and naturally there is a more prolific supply of examples in this field. Hence, the attention of the reader has been and will continue to be directed to this particular application.

Wage Payment.—From the wage-payment viewpoint, it is necessary, of course, to have a good wage-payment plan in order to realize fully the economic value of time study. Every good wage-payment plan provides that earnings will be determined by the amount of useful work accomplished. In some systems, compensation is directly proportional to output; if output is

doubled, earnings are doubled. The straight piece-work plan is a good example of this type. Other plans provide that earnings increase with increased output but not in the same proportion, on the theory that increased output does not necessarily demand a proportional increase in effort.

Another way in which wage-payment plans differ is in the terms used to express job allowances. The two chief ways of expressing allowances are directly in terms of money and in terms of so many units of time. Referring again to the straight piece-work system, one finds there the best example of using money directly as the allowance for each unit of output. For every unit completed, the worker is paid a definite amount of money, and the computation of his total earnings over a definite time is a very simple matter. The number of units completed is merely multiplied by the amount of money allowed for each. In the majority of approved systems, however, the unit allowance is expressed as so much time, and by various methods of calculation involving the total of the time allowance and a monetary rate, the earnings are calculated.

In any case and regardless of the wage-payment plan being used, the fundamental method for determining unit allowances is time study. The allowed time as determined by time study may be used without alteration, or it may be converted into other terms according to the wage-payment plan in use, but it must be remembered that time study is the foundation of the entire structure.

Individual Job Values.—Many time studies are made with no other object than to establish a time value for the one particular job under consideration, and with this done, there is apparently no other immediate use for it. It is accordingly filed away against the time when some future use for it might develop.

Time-study Reference File.—This file should be maintained so that the individual time studies may be readily found for reference purposes. There are various methods of filing time studies, depending upon local plant conditions and subdivisions of manufacturing operations. In one case, it may be best to file studies by the departments in which the work was performed; in other cases, classification according to classes of work or types of machine tool equipment may be best.

This file will be comprised largely of miscellaneous studies on various lines of work on which sufficient studies have not been

made to make possible the construction of a formula, because of the low activity of the work or because of an insufficient number of trained time-study men in the organization to do more than take care of immediate pressing demands. Some of the individual studies will probably be independent of and have no relation to the others, having been made with no other object than to determine a time allowance for one particular job. To make a time study with this single purpose in view may be justifiable, and it may even be justifiable to do it again and again, but if there are frequent repetitions on similar jobs that fall in the same general class of work, the uses of the data secured from representative studies may be extended to cover the entire class of work. This may be done by compiling standard data or by constructing formulas by which the time value may be readily determined for any job in the class, without the necessity of actually making a separate time study.

Standard Data.—A compilation of standard data is merely a list of all the different elements that have occurred in all the time studies made on a given class of work and the corresponding time values for each. Every element that differs even slightly from every other element has its own time value. When a job comes up on which no time value has been previously established, the standard data are referred to and a time value selected for each of the elements of the job. It is generally necessary to go on the floor and make an analytical motion study in order to determine the elements that are required for the operation. It may be found that some of the elements of the jobs are not included in the standard data because they had not previously occurred in any of the studies from which the list was made. In this case, those elements should be studied and included with their time values in the standard data.

The standard-data method is frequently used to advantage on machining operations where a considerable part of the time for the operation is cutting time which can be calculated from the speed, feed, and depth of cut. A list is generally made up for each type of machine tool, and this list includes values for the various motions necessary for the manipulation and operation of each particular machine. In other words, a study is made of the machine rather than the work. The merit in this plan is readily seen when one considers that the piece upon which the work is being done will have little, if any, influence on the time required

to manipulate the different parts of the machine, because they have a definite mechanical relation to each other. For example, such elements as "start machine," "stop machine," "release

Sheet 1

STANDARD DATA—AVEY SENSITIVE DRILL PRESS

Procedure for Using Avey Sensitive Drill Press Data

1. Determine by observation the elemental operations performed.
2. Pick out the proper time for each operation from sheet 3 or 4.
3. Measure the distance of metal to be drilled and add the length of the drill lead (as specified in table on Sheet 1 or 2) and multiply that sum by the proper time to drill 1 inch as shown in table on Sheet 1 or 2.
4. The total sum of all the values selected will be the time allowed to perform the operation on each piece.
5. Time values for tapping operations are found by using the formula shown on Sheet 2.
6. Time values for setting up the machine are shown on Sheet 5.

TABLE OF DRILLING VALUES

Time to Drill 1 Inch with Hand Feed

Drill diameter in inches	Length of lead in inches	Brass		Cast iron		Medium steel	
		Speed. Revolutions per minute	Time in hours	Speed. Revolutions per minute	Time in hours	Speed. Revolutions per minute	Time in hours
Carbon-steel drills							
1/8	0.037	4,750	0.00102	1,240	0.00425	1,020	0.00680
9/64	0.042	4,250	0.00110	1,060	0.00450	900	0.00740
5/32	0.047	3,850	0.00118	920	0.00475	820	0.00780
11/64	0.051	3,500	0.00124	850	0.00500	740	0.00820
3/16	0.056	3,250	0.00130	830	0.00515	680	0.00860
13/64	0.061	3,000	0.00136	830	0.00530	640	0.00890
High-speed steel drills							
7/32	0.065	2,750	0.00140	1,360	0.00270	1,010	0.00600
15/64	0.070	2,550	0.00145	1,300	0.00275	960	0.00610
1/4	0.075	2,400	0.00148	1,240	0.00280	910	0.00620
17/64	0.080	2,200	0.00151	1,170	0.00285	870	0.00630
9/32	0.084	2,050	0.00155	1,120	0.00290	830	0.00640
19/64	0.089	1,950	0.00160	1,070	0.00295	790	0.00650
5/16	0.094	1,800	0.00162	1,020	0.00300	750	0.00660

FIG. 115a.—Standard data for Avey sensitive drill press.

power feed," "remove tool," and "adjust stops" should require the same amount of time regardless of differences in pieces being worked upon. The work that can be done on a particular machine tool is limited by the physical characteristics and dimensions of

Sheet 2

TABLE OF DRILLING VALUES

Time to Drill 1 Inch with Hand Feed

Drill diameter in inches	Length of lead in inches	Brass		Cast iron		Medium steel	
		Speed Revolutions per minute	Time in hours	Speed Revolutions per minute	Time in hours	Speed Revolutions per minute	Time in hours
High-speed Steel Drills							
21/64	0.098	1,700	0.00164	975	0.00305	730	0.00670
11/32	0.103	1,600	0.00165	930	0.00310	700	0.00680
23/64	0.108	1,550	0.00168	885	0.00315	670	0.00690
3/8	0.113	1,500	0.00170	845	0.00320	640	0.00710
25/64	0.117	1,450	0.00172	805	0.00325	610	0.00720
13/32	0.122	1,375	0.00175	770	0.00330	590	0.00730
27/64	0.127	1,325	0.00177	740	0.00335	565	0.00740
7/16	0.131	1,275	0.00179	710	0.00340	540	0.00750
29/64	0.136	1,225	0.00181	680	0.00345	520	0.00760
15/32	0.141	1,175	0.00183	660	0.00350	500	0.00770
31/64	0.145	1,150	0.00183	635	0.00355	480	0.00780
1/2	0.150	1,125	0.00187	615	0.00360	460	0.00790
33/64	0.155	1,075	0.00189	595	0.00360	440	0.00800
17/32	0.159	1,050	0.00191	575	0.00365	430	0.00810
35/64	0.164	1,025	0.00193	555	0.00370	420	0.00820
9/16	0.160	1,000	0.00195	540	0.00375	410	0.00830
37/64	0.173	975	0.00197	520	0.00380	400	0.00840
19/32	0.178	950	0.00201	505	0.00385	390	0.00860
39/64	0.183	950	0.00203	485	0.00390	380	0.00870
5/8	0.188	925	0.00204	475	0.00395	370	0.00880
41/64	0.192	900	0.00206	460	0.00400	365	0.00890
21/32	0.197	875	0.00208	450	0.00405	355	0.00900
43/64	0.202	850	0.00210	440	0.00410	345	0.00910
11/16	0.206	825	0.00212	435	0.00415	340	0.00920
45/64	0.211	800	0.00214	430	0.00420	330	0.00930
23/32	0.216	800	0.00216	425	0.00425	320	0.00940
47/64	0.221	775	0.00218	420	0.00430	310	0.00950
3/4	0.225	750	0.00220	420	0.00430	300	0.00960

Tapping Time

$$\text{Tapping time} = \frac{(D + d)P}{\text{R.P.M.}} \times 1.5 \times 0.0167 \times 1.22$$

where D = depth tapped
d = length of lead (equivalent of tap diameter, allowing for overrun)
P = pitch (number of threads per inch)
1.5 = factor covering tapping and reversing at twice the tapping speed
0.0167 = decimal hour equivalent of 1 minute
1.22 = allowance for fatigue, delays, tool upkeep, and machine oiling and cleaning

FIG. 115*b*.—Standard data for Avey sensitive drill press.

the machine. Hence, it is logical that the machine itself should be made the basis of study on work of this kind rather than the piece or part being made. Figures 115*a* to 115*e* inclusive illustrate the form in which standard data are compiled. This particular set of standard data was compiled for setting time values on drilling done on No. 2 Avey sensitive drill presses.

Sheet 3

AVEY SENSITIVE DRILL PRESS STANDARD OPERATIONS

Part Handling

		Hours
1.	Set small part in jig	0.0013
2.	Set medium part in jig	0.0018
3.	Set large part in jig	0.0021
4.	Tighten screw or locater (per screw) by hand	0.0021
5.	Tighten screw or locater (per screw) spanner wrench	0.0040
6.	Tighten thumb nut (per thumb nut) by hand	0.0008
7.	Tighten Hex nut (per nut) use open-end wrench	0.0018
8.	Close cover (all sizes)	0.0003
9.	Put on cover	0.0020
10.	Put on clamp (per clamp)	0.0010
11.	Release thumb nut (per thumb nut) by hand	0.0004
12.	Release Hex nut (per nut) use open-end wrench	0.0016
13.	Open cover	0.0003
14.	Remove small and medium parts from jig	0.0009
15.	Remove large parts from jig	0.0014
16.	Remove clamp (per clamp)	0.0019
17.	Place small or medium part on drill table	0.0006
18.	Place large part on drill table	0.0009
19.	Remove small or medium part from drill table	0.0006
20.	Remove large part from drill table	0.0012
21.	Move small jig or part to first spindle	0.0005
22.	Move medium jig or part to first spindle	0.0012
23.	Move large jig or part to first spindle	0.0016
24.	Move small jig or part from spindle to spindle	0.0005
25.	Move medium jig or part from spindle to spindle	0.0012
26.	Move large jig or part from spindle to spindle	0.0016
27.	Move small jig or part from hole to hole	0.0004
28.	Move medium jig or part from hole to hole	0.0008
29.	Move large jig or part from hole to hole	0.0010
30.	Get small part	0.0006
31.	Get medium part	0.0007
32.	Get large part	0.0010
33.	Place small part in vise and tighten	0.0024
34.	Place medium part in vise and tighten	0.0024
35.	Place large part in vise and tighten	0.0024
36.	Release vise	0.0009
37.	Remove and lay aside small part	0.0015
38.	Remove and lay aside medium part	0.0017
39.	Remove and lay aside large part	0.0017
40.	Blow cuttings from small or medium jig (air hose)	0.0014
41.	Blow cuttings from large jig (air hose)	0.0020
42.	Clean jig (turn over)	0.0014
43.	Clean jig with brush	0.0018
44.	Insert or remove bushing	0.0005

FIG. 115*c*.—Standard data for Avey sensitive drill press.

It includes, besides time values for all elements which will be performed in making set-ups and in drilling cast-iron, steei, and brass parts, tables of drilling and tapping time values. Thus it is possible to establish time values by merely noting what elements must be performed and by determining the number. size, and depth of holes drilled.

Sheet 4

AVEY SENSITIVE DRILL PRESS STANDARD OPERATIONS

	Hours
Drill from Layout	
45. Move small part from hole to hole	0.0006
46. Move medium part from hole to hole	0.0010
47. Move large part from hole to hole	0.0012
48. Move small part from spindle to spindle	0.0007
49. Move medium part from spindle to spindle	0.0014
50. Move large part from spindle to spindle	0.0016
Redrill, Countersink, or Burr	
51. Move to spindle	0.0005
52. Move from hole to hole	0.0004
53. Move from spindle to spindle	0.0005
Machine Handling	
1. Raise or lower spindle	0.0003
Machining	
1. Drill (see chart)	
2. Tap (see chart)	
3. Redrill fiber (per inch)	0.0010
4. Countersink metal (light)	0.0001
5. Countersink fiber (light)	0.0001
6. Countersink metal (deep)	0.0002
7. Countersink fiber (deep)	0.0002

FIG. 115*d*.—Standard data for Avey sensitive drill press.

Sheet 5

AVEY SENSITIVE DRILL PRESS SET-UP VALUES

	Hours
A. Set jig or vise on table	0.0061
B. Check drawing	0.0220
C. Place tool or chuck in spindle	0.0012
D. Place tool in chuck	0.0042
E. Remove tool or chuck from spindle	0.0026
F. Remove tool from chuck	0.0050
G. Place tapper in spindle	0.0029
H. Place tapper collar on spindle	0.0036
I. Tighten tapper collar	0.0066
J. Loosen tapper collar	0.0068
K. Remove tapper from spindle	0.0020
L. Place tap in tapper	0.0147
M. Remove tap from tapper	0.0029
N. Set table to proper height	0.0115
O. Place speed-reducing pulley on spindle	0.0184
P. Remove speed-reducing pulley from spindle	0.0086
Q. Set spindle support	0.0050
R. Set spindle stop	0.0091
S. Clean table	0.0204
T. Sort out tool (each)	0.0113

Total time allowed for first piece =
(values selected from above table) + (time allowed for each piece).

FIG. 115*e*.—Standard data for Avey sensitive drill press.

Figure 116 shows how a motion study is taken on the operation of drilling a hole $\frac{17}{64}$ inch in diameter $\frac{3}{16}$ inch deep in a cast-iron bracket held in a jig. Every elemental operation performed is recorded while actually watching the work being done. The time-study man may then fill in the standard allowed time for

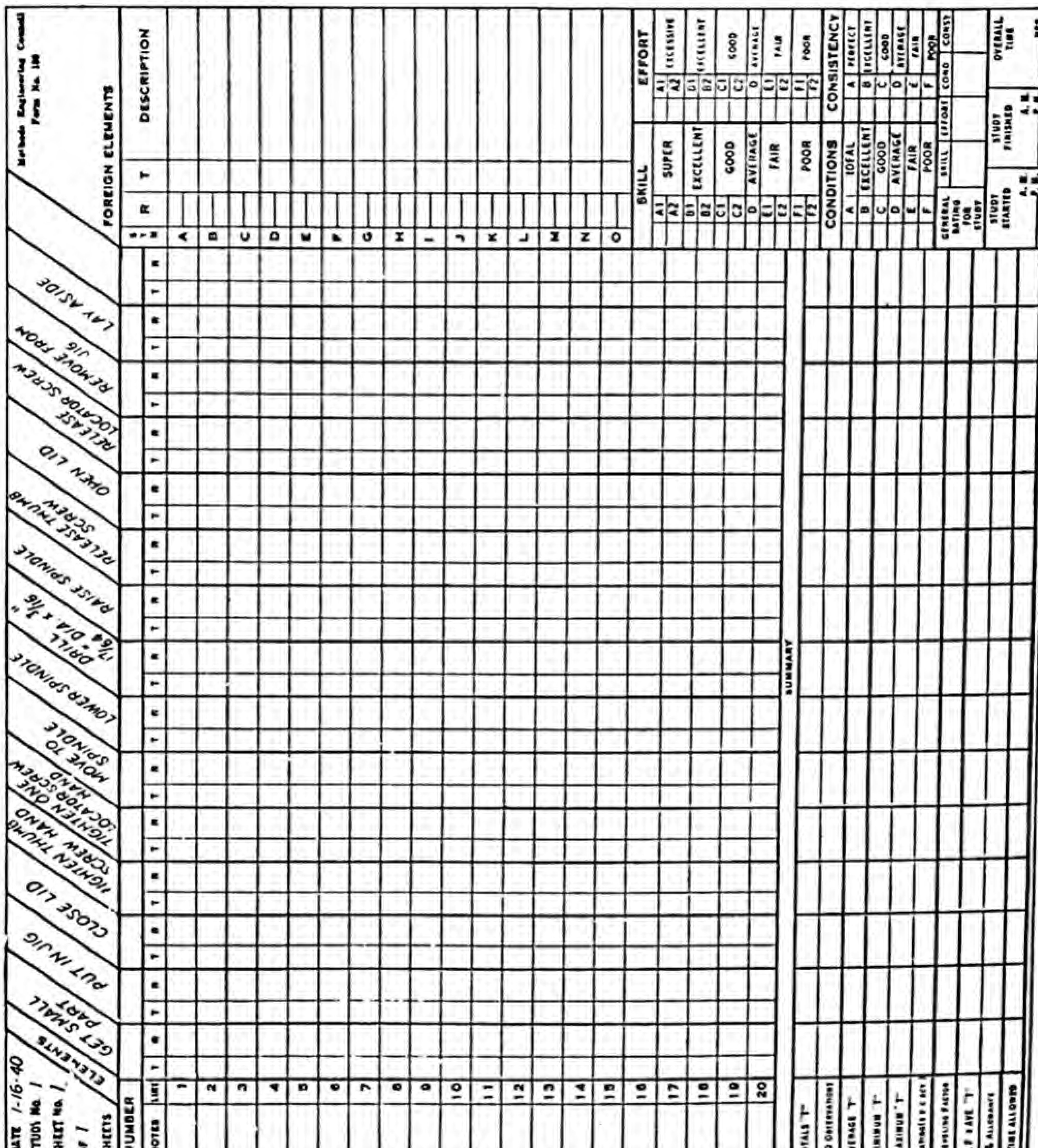


FIG. 116.—Element breakdown of drilling operation.

each element from the value given in his standard data as shown in Fig. 117. Since drilling time per inch is given by the drilling table, he is able to compute drilling time for any depth of hole by multiplying the table value by the depth drilled plus the lead for the proper size of drill.

The back of the time-study form is then filled out as shown in Fig. 118. A list of the elements allowed for the set-up together

with the corresponding time values should be here shown. The computations for arriving at the allowed drilling time and the final established time value should also be given. Aside from this, only enough information clearly to identify the job need be recorded. After the time value has been established, the time-

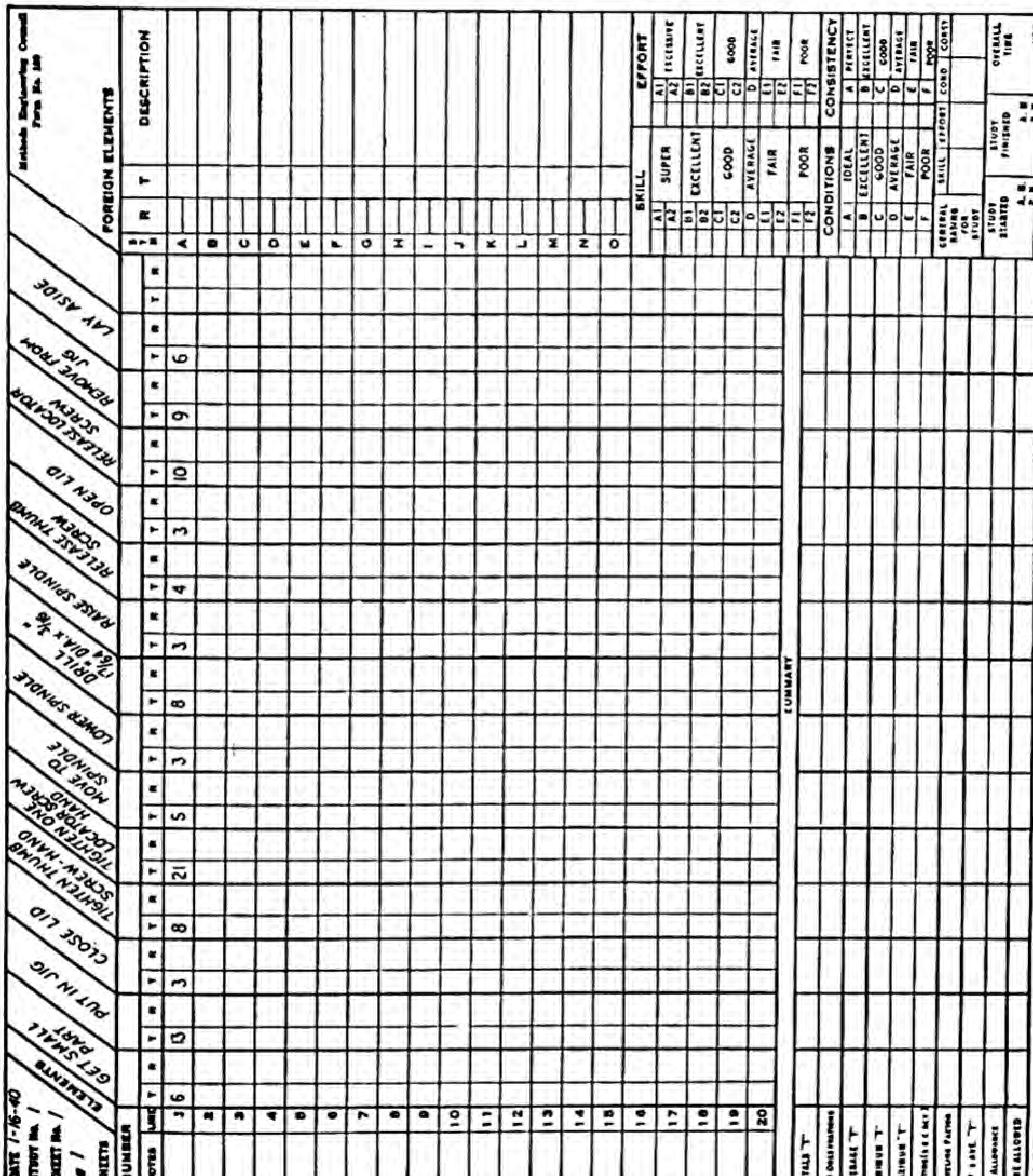
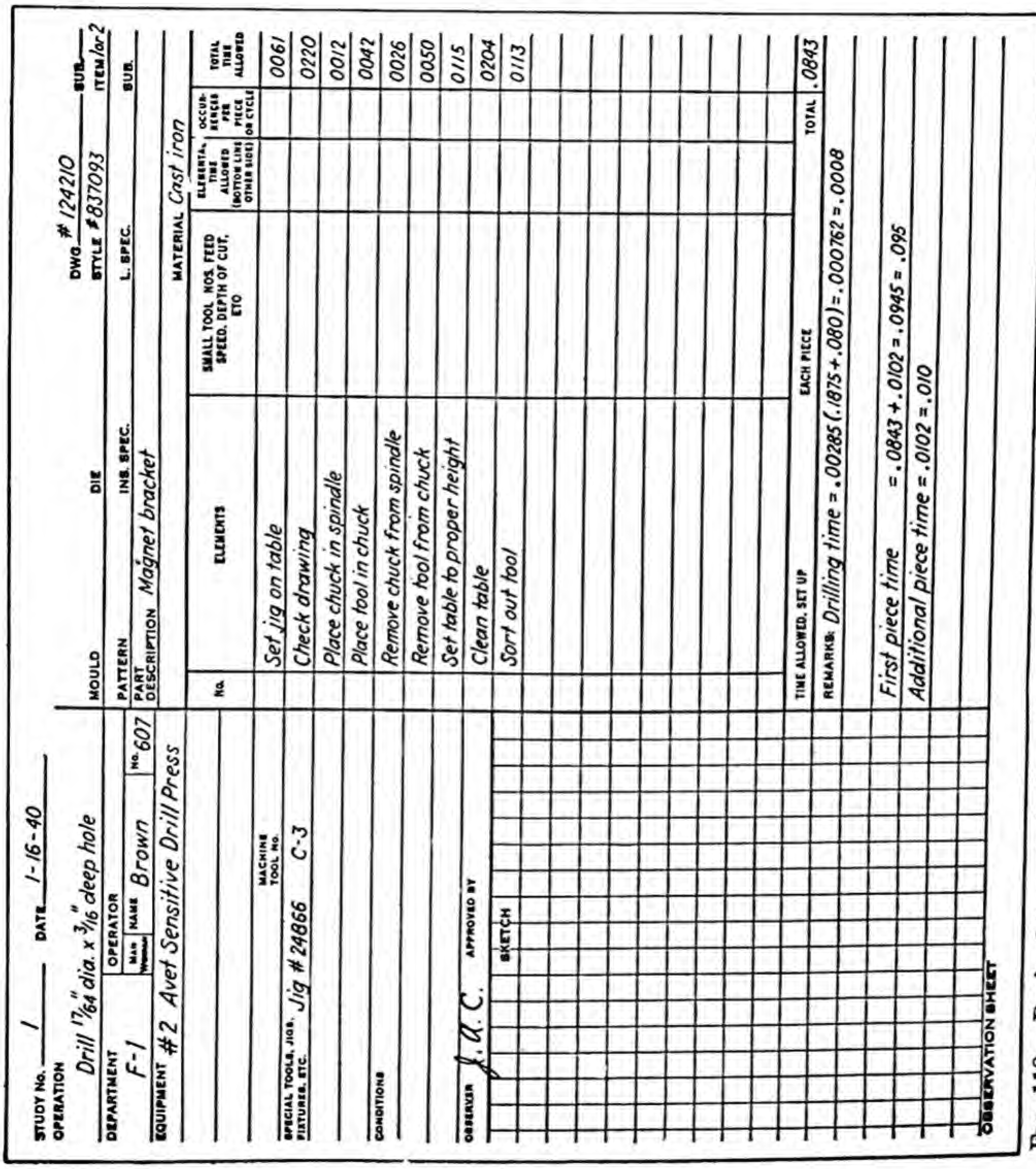


FIG. 117.—Element breakdown of drilling operation with appropriate values filed in from standard data.

study sheet should be filed away so that it will be available for reference if at any future time the established value is questioned.

The Formula.—The method in which time-study data are most profitably employed is in the construction of formulas for setting time values. A comparatively small number of good representative time studies is sufficient material with which to make a

formula that will apply to the entire class of work. The obvious advantages of using time-study data in this way are that considerable time is saved in establishing time values by formula rather than by individual time study; that the values are more likely to be consistent; that they can be determined from working


STUDY NO. 1 DATE 1-16-40
OPERATION Drill 17/64" dia. x 3/16" deep hole
DEPARTMENT F-1 OPERATOR MAN/WOMAN NAME Brown NO. 607
EQUIPMENT #2 Avet Sensitive Drill Press
SPECIAL TOOLS, JIGS, FIXTURES, ETC. Jig #24866 MACHINE TOOL NO. C-3
CONDITIONS
OBSERVER J. A. C. APPROVED BY
SKETCH
OBSERVATION SHEET
MOULD DIE DWG #124210 SUB.
PATTERN INS. SPEC. STYLE #837093 ITEM 1 or 2
PART DESCRIPTION Magnet bracket L. SPEC. SUB.
MATERIAL Cast iron

NO.	ELEMENTS	SMALL TOOL NOS. FEED SPEED, DEPTH OF CUT, ETC.	ELEMENTAL TIME ALLOWED (BOTTOM LINE OTHER SIDE)	OCCURRENCES PER PIECE OR CYCLE	TOTAL TIME ALLOWED
	Set jig on table				0061
	Check drawing				0220
	Place chuck in spindle				0012
	Place tool in chuck				0042
	Remove chuck from spindle				0026
	Remove tool from chuck				0050
	Set table to proper height				0115
	Clean table				0204
	Sort out tool				0113

TIME ALLOWED, SET UP EACH PIECE TOTAL .0843
REMARKS: Drilling time = .00285(.1875+.080) = .000762 = .0008
First piece time = .0843+.0102 = .0945 = .095
Additional piece time = .0102 = .010

FIG. 118.—Back of time-study sheet showing information which must be recorded when establishing a time value from standard data.

drawings and other manufacturing information without the necessity of actually observing the operation being performed; and that a high-grade analytical time-study man is not required to apply the formula even though he might have been required to make it.

PART II

FORMULAS

CHAPTER XXIV

PRINCIPLES OF FORMULA CONSTRUCTION

In the first part of this book, the formula has been mentioned several times when bringing out reasons for certain details of the procedure for making time studies. Just what was meant may have been somewhat vague to those who are unfamiliar with the application of formulas to the work of establishing time allowances. It is the purpose of this chapter, therefore, to give a general idea of what formulas used in this connection are before passing on to a detailed account of how they are compiled.

Formulas and Their Application to Time-study Work.—A formula may be defined as the expression of a general fact, rule, or principle by algebraic symbols. It is a convenient way of expressing the manner of variation between two or more interdependent variables. When all but one of the variable quantities are known for a given set of conditions, it is quite easy to find the unknown quantity by substitution in and solution of an algebraic formula. It must be remembered that the formula is only a convenient way of expressing a rule and is not the rule itself. In using formulas in general, there is a tendency to substitute and solve blindly, without first examining the rule expressed by the formula and ascertaining whether or not it is applicable to the case under consideration.

The algebraic formula was probably first confined to the field of mathematics. Its convenience and conciseness were readily apparent, and it was naturally extended to physics, mechanics, electricity, and all branches of applied science. Today the formula is used for expressing such general principles as the laws of economics where actual substitution is never made but where the general relationship of several interdependent quantities is shown.

When time study was first introduced into industry, a separate study was taken on each job as it came along. This required

considerable time and effort and led to the feeling that time study could be applied only to standard lines of work where quantities were large and operations few. It is readily conceivable that the taking and working up of time studies on work of a varied nature might require nearly as many time-study men as operators.

It is by no means necessary, however, to time study every job that comes through the shop. Time-study men were quick to recognize that certain elemental operations in a given class of work were constant regardless of the nature of the piece upon which work was being done. Other elemental operations varied with certain characteristics of the work.

The recognition of these facts led to the compilation of standard data, a sample of which has already been shown in Chap. XXIII. It then became apparent that certain operations were performed on every piece worked, that others were performed when the piece had certain characteristics, and that the time for doing still other operations varied in a definite manner with certain variable characteristics such as length, area, or volume. The next step, that of resolving standard data into algebraic formulas, followed as a matter of course.

Advantages of Formulas.—The great amount of time which the use of formulas will save the time-study man is readily apparent. The time required to take and work up a time study on repetitive work will be from 1 to 4 hours where the length of the operation cycle is fairly small, and may be much longer on larger work where one operation cycle may run as high as 100 hours. The time required to set a time value from a formula will, in the majority of cases, range from 1 to 15 minutes, depending on the complexity of the formula and the amount of time required to determine the characteristics of the job. Where all necessary information may be obtained from the drawing of the part, the time value may generally be computed in less than 5 minutes.

With so much time saved in the work of the time-study department, it is obvious that formulas will enable fewer men to cover a given amount of work or the same number of men to handle a much larger territory. The caliber of men required to apply formulas need not be so high as that of men who must take time studies. It is thus possible for a plant to have a few expert time-study men who will do all of the work discussed in Part I of this book and who will also compile all formulas. The rest of

the work, that of setting time values from formulas, may be carried on by men better fitted for routine work and incidentally commanding less salary. In passing, it might be mentioned that such a set-up provides a direct line of promotion within the time-study organization. Good men are willing to accept the routine job and will maintain an interest in their work if they know that they will have a chance to advance to the more highly paid more interesting time-study and formula work as soon as they have fitted themselves for the job.

Formulas have made possible the application of time-study methods and incentive plans to the job shop. Without them the cost of establishing time values would offset the savings which incentive plans produce, great as they are. With formulas, a large volume of time values may be set by a comparatively few time-study men with a large net saving to the plant. Indeed, formulas are highly profitable on all but strictly standard work where operations are so few that it would take longer to compile formulas than to set values by actual time studies.

Where all time values are set by time study, some inconsistencies are almost certain to appear. Because of errors in judgment, unnecessary work that was allowed to pass unnoticed, and variations in the judgment of several time-study men who handled the work over a period of time, some time values will be easier to meet than others. Simple jobs will, in some cases, have higher time values than much harder jobs upon which more work must be performed. Such inconsistencies tend to decrease the respect of the workers for time study and time-study methods. It takes but one or two "wild" values to shake the confidence that hundreds of correct values have built up.

The only chance for inconsistency when time values are set by formula is in an error in determining the variables which will be substituted in the formula or in the mathematical solution of the formula. Usually such slips will give time values so far out of line that the time-study man will see at once that he has made an error and will check his work. If a wrong value does get as far as the worker and he complains, it is a simple matter to recheck the job and determine whether or not the complaint is justified. Once the worker has been satisfied with the fairness and accuracy of a formula, he will very seldom ask for a recheck of a job unless he is reasonably sure that an error has been made.

If no formulas are available on a certain class of work, the time-study man has a difficult time giving accurate labor estimates on contemplated new work. He must take the drawings of the new parts, try to visualize what operations must be performed, and then estimate how long it will take to do each operation. His estimates will be little better than guesses, although he tries to use his best judgment in making them.

If formulas are available, the time-study man is able to give estimated time values, which, in the majority of cases, will be the same as the actual values which will be set when the job comes through the shop. He will get what information he needs from the drawings and will use his formula in determining time values. Unless the drawing does not give him all the information he needs, he will arrive at exactly correct time values. The importance of having accurate labor estimates becomes readily apparent when it is realized that the sales department is guided by factory costs in making bids for new business. If the cost furnished is higher than it should be, the price offered will be high, and the company will not obtain the order. If the estimated cost is lower than the actual cost, the company will very probably get the order and be obliged to fill it at a loss.

Scope of Formulas.—It is thought by those who have but a superficial knowledge of formula work that formulas can be applied only to machine work where feeds, speeds, depth of cut, and the like are the only variables. The fields in which formulas have been successfully applied are, however, very much broader than that. Practically any line of work may be formulated accurately if sufficient data are first collected. This statement may appear rather broad to those who have not dealt intimately with formulas, but glance for a minute at some of the operations upon which time values are being set daily by formulas.

All kinds of machine work.
Bench fitting and assembling.
Wiring.
Panel mounting.
Bench, machine, and floor molding.
Bench and machine core making.
Casting cleaning.
Foundry furnace work.
Metal ratios or yields.
Arc welding.

Drop forging.
Chipping with air hammer.
Coil winding, taping, and insulating.
Copper forming (miscellaneous).
Motor assembly.
Structural metal assembling.
Painting.
Window washing.
Janitor work.
Maintenance work.
Wooden-box making.
Storeroom work.
Tool making.
Pipe fitting.

These examples should suffice to show the practically limitless scope of formulas.

Characteristics of a Formula.—A formula, above everything else, must give accurate time values. If it does not, it is practically valueless. It does not do, where avoidable, to construct a formula which will give time values too low in some cases and too high in others, even though when averaged the time values are about right. The workers will continually complain about the low values and minimize the balancing effect of the high. They rightly wish every time value to be correct. If the formula is not accurate, it is very difficult to convince the workers of the fairness of establishing time values in this manner.

Very often trouble is encountered by trying to set time values on jobs to which the formula does not apply. If a job is encountered which is too large to come within the limits of the curves which are used to show variable relations, it is a temptation to extend these curves and establish a time value accordingly. In many cases, the resulting time value will not be correct. Thus the class of work to which the formula applies should be clearly stated, and all jobs which fall outside of this class should be covered by other formulas if numerous, or time studied individually if few.

A formula, in order to be quickly and easily applied, should be as clear and concise as possible. All constant elemental operations that occur on every job should be summed up into one general constant. The variables should be expressed as simply as possible. A later chapter will show various ways of expressing variables in table, curve, and chart form which will greatly simplify the task of applying the formula. All percentages that are to be added should be included in the formula constants and

variables and should not be left dangling at the end of the formula expression to be added by a separate extra multiplication. Such simplification will not only save considerable time for the routine man who is applying the formula, but it will also reduce the possibility of clerical errors.

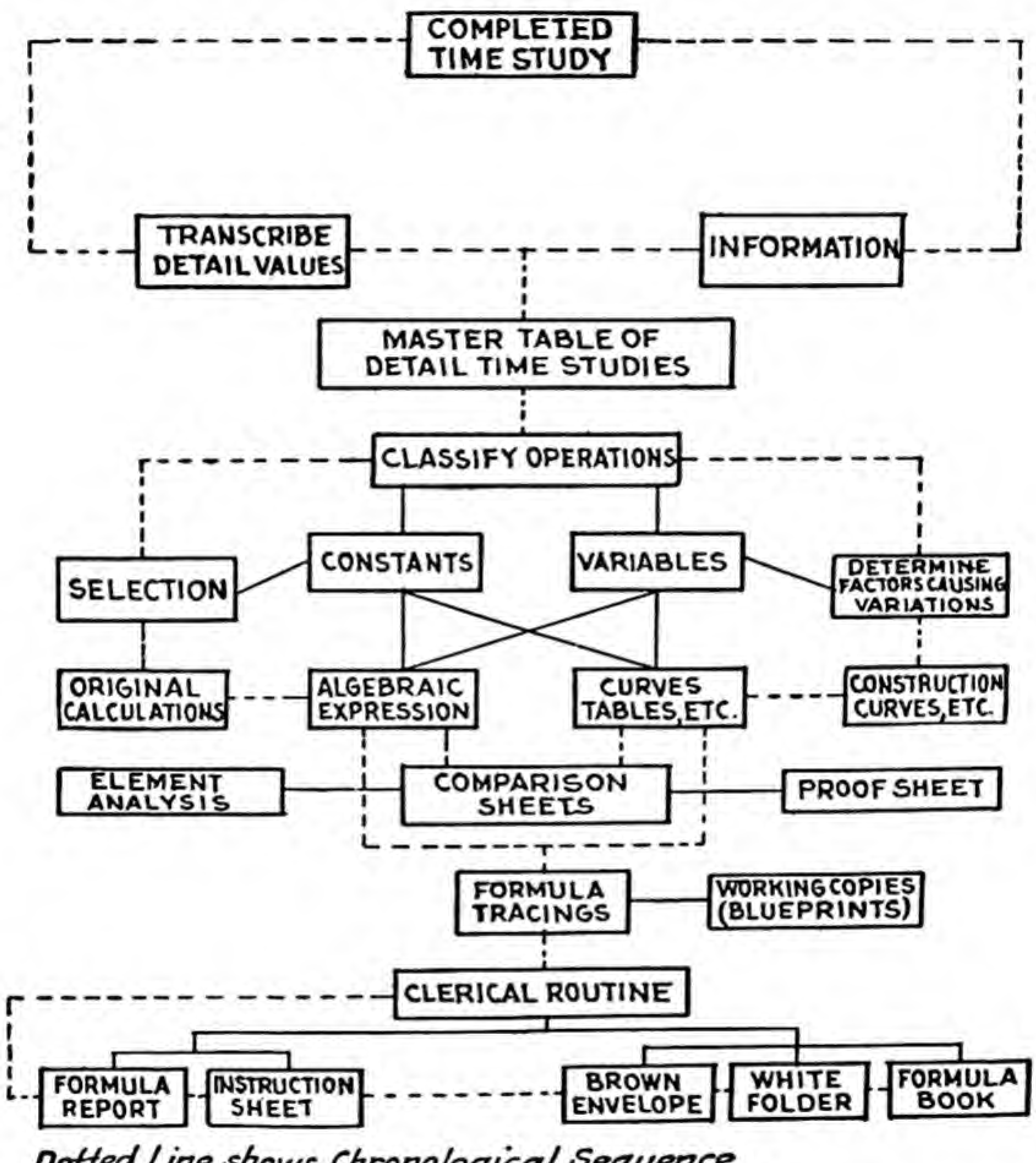


FIG. 119.—Graphic analysis of elements of a formula.

Elements of a Formula.—The first step in compiling a formula is the making of a general analysis of the work to be covered. This analysis is similar to that made when taking an individual time study, but it is somewhat broader in that it covers the class of work as a whole and not merely the individual job.

After a clear idea has been formed of what the formula will cover and what work its construction will entail, the next step is the actual collecting of data. This consists of taking detail

time studies on a number of representative jobs. These data are then assembled into a Master Table of Detail Time Studies. as will be described fully later.

There then comes the task of classifying each individual elemental operation as either a constant or a variable. Just which it is is not always readily apparent, and it requires a man of no little analytical ability to do this work. After the elemental operations have been classified, it is necessary to select a definite time value for each elemental constant and to make a further analysis of each elemental variable to determine just how and with what it varies.

When all constants and variables have been determined, there remains only the task of expressing the formula in its simplest terms and making a report which will explain clearly the construction and application of the formula.

In order to aid the visualization of the relation to one another of the various steps taken in compiling a formula, the chart shown in Fig. 119 has been made. Each step is taken up and fully discussed in detail in the succeeding chapters.

CHAPTER XXV

GENERAL ANALYSIS AND SURVEY

Before taking a time study, it is necessary to analyze the job, and similarly, before starting to collect data for the compilation of a formula, a general analysis should be made. The latter analysis is, from its purpose, broader than the former. It embraces all the details of the time-study analysis from the wider viewpoint of the formula, and it includes some details not heretofore considered.

The analysis should be made before data are collected in order to insure that all necessary and only necessary data be obtained. It is perfectly possible to make the analysis during the actual steps of formula construction, but it will be found that much effort is expended uselessly. In this chapter is set forth the procedure for making a general advance analysis and survey in preparation for the making of a formula. The steps in this procedure will be found to overlap in practice, but they are here given in as nearly chronological order as possible.

Determining the Field of the Formula.—First of all it is necessary to determine the field to which the formula is to apply. This may not be done entirely in advance, but the field may be narrowed to one general class of work. For instance, it is decided to place molding work in a foundry on an incentive basis. The time-study man surveys the molding work as a whole and discovers that by far the greater part of the work is done on vibrator molding machines. In order to gain the greatest results, he decides to formulate vibrator machine molding work. Thus he has determined in a general way the class of work to which the formula will apply, although he may later find that certain considerations make it advisable to limit the formula to jobs made in two-part flasks and to cover other kinds of vibrator machine work by other formulas. Similarly, other fields of work would be mentally determined, such as sensitive drill presses, engine lathes, band saws, blacksmithing, or panel wiring, leaving the actual limits of application to be fixed after more detailed study.

Inspection Requirements.—Inspection requirements must be determined as in the case of the individual time study, so that the time-study men may know definitely just what operations must be performed and what standards of accuracy, finish, and the like are to be maintained. He views the requirements considering the work as a whole and carefully considers whether or not they are suitable to insure work of good quality without going to wasteful extremes. The thoroughness with which he must consider the inspection requirements depends upon the nature of the work. The foundry inspector requires that a casting when molded and poured be filled out in all its parts, that it have no shifts or sections out of place due to washed sand or cores, that the metal be right, and similar simple fundamental requirements so obvious as to require little or no examination on the part of the time-study man. On the other hand, the requirements for bench fitting and assembly of a varied line of apparatus are many, and the time-study man must spend considerable time studying them and considering their justness.

Mental Study of the Operation.—After the time-study man has satisfied himself that the inspection requirements are as they should be, he should make a thorough mental study of the operation itself. He must become familiar with the methods used in doing the work in order that he may plan how best to formulate it. This mental study is made merely by observing the work as it is being done. The time-study man will observe each elemental operation and consider why it is necessary. He will assure himself that each operator is using the best methods, and if there is any variation, he will determine which is the best. If he has previously been establishing time values on this work by time study, he will already have a good working knowledge of the operation, but he should nevertheless spend some time considering the work as a class. It is very possible that he will discover certain points that have passed unnoticed before when he was concentrating on single jobs.

Survey of Conditions and Recommendations for Improvements.—At the same time that he is making a mental study of the operation, the time-study man will be making a survey of conditions. First, he will note working conditions such as light, heat, ventilation, and location of drinking fountains. He will more especially study material-handling conditions. He will note how raw material is brought to the worker and how the

finished product is removed. He will investigate all material-handling equipment, and he will study the machine equipment itself. Again he studies the points which have been dwelt on at some length in Chap. VI, but from a more general viewpoint.

This general survey will in most cases reveal conditions which may be bettered. Improved handling devices, convenient location of supplies, and devices which will eliminate fatigue and increase production will naturally suggest themselves to the time-study man. When he has completed his survey, he should recommend all of these changes to the proper authority. This recommendation may be oral in the case of a few minor improvements, or it may be in the form of a formal report including estimated costs and savings where the changes are more comprehensive.

The general survey may not amount to much where conditions have been carefully considered before, or it may be the major part of the work of making the formula. For example, when a group of men melting and distributing metal in a foundry were studied, the general survey revealed that many devices could be installed which would make the work easier physically and at the same time reduce the size of the furnace crew.[1] These devices were carefully worked out, and a report was drawn up showing what should be done to improve conditions. The report was discussed at considerable length by those concerned, and finally it was agreed to adopt certain of the recommendations. Some new equipment had to be designed and built, and it was some time after the original survey was made before conditions were improved. Not until this was completed could the formula be made and the work put on an incentive basis. The furnace operation had been a strictly day-work proposition and little attention had been paid to conditions. The time-study man was in this case practically a pioneer, and the part of his work which brought about the biggest saving was the making of the general survey and the writing of the report.

Enlisting the Interest and Aid of the Worker.—If the workers who are to be studied have never worked on an incentive basis before and if they are entirely unfamiliar with time-study methods, they must be approached at first in the manner described in

[1] For a more complete description of this study, see by H. B. Maynard and G. J. Stegemerten, "Operation Analysis," Chap. IV, McGraw-Hill Book Company, Inc., New York, 1939.

the early part of this book. After they have learned something about the fairness of time-study work, they may be further told about the purpose of making formulas and the advantages to all concerned of establishing time values in this way.

Where workers have already been working under incentives established by time study, the purpose of making the formula may be explained without any introductory remarks. This should be done after enough mental study of the operation has been made to enable the time-study man to talk intelligently about the work. If the time-study man starts to study work upon which values have already been established without explaining his reasons, the workers are very likely to feel that the purpose of the study is to reduce time values and earnings, and they quite naturally will resent it. If, however, the time-study man explains that he is collecting data from which he will eventually be able to establish consistent time values on all jobs and if he guarantees that earnings will be unaffected if effort is maintained, the workers will have no cause for suspicion. Some may wish to know how he proposes to do this, and then the time-study man can explain briefly the general principles of formula construction, using simple examples drawn from the work on which his questioners are engaged which they will readily understand.

Not only should he thus arouse interest in the work which he is doing, but he should also encourage any suggestions on the part of the workers about improved methods or conditions. The time to make changes is before the formula is put into effect. Subsequent changes will be more costly, for then all time values must be revised. The workers will often have valuable ideas concerning the improvement of working conditions, for they realize through intimate contact any retarding factors which may exist. The time-study man, by working out these ideas and in having them put in effect, will not only benefit the employer, but he will win the lasting good will of the workers.

Trial Division of Elements.—The last step before the actual taking of time studies is the making of a trial division of elemental operations. All time studies are later to be recorded on a Master Table of Detail Time Studies. By comparing the time taken for a certain element on one study with that taken on other studies, it is possible to determine whether or not the elemental operation is a constant and, if not, how it varies. In order to make this comparison, it is necessary that the opera-

tion be divided up into its elements in the same way on all studies. For example, the elemental operations, "get part from table," "place in fixture," and "close cover," all should be divided as given on all studies and not appear as "get part from table and place in fixture" and "close cover" in one study and "get part from table" and "place in fixture and close cover" in another. Such a variation in division of elements will more than double the work of compiling the formula and will seriously affect the accuracy of the results.

A division of elements should first be made on a job selected at random, dividing the operation into as small elements as is consistent with accuracy. This division of elements should be considered carefully, and the attempt should be made to keep constant and variable operations completely separated, in so far as analysis will show the operation to be constant or variable. Other jobs should be considered in the light of the trial division of elements, until finally a sequence of operations is determined which will be applicable to all jobs.

CHAPTER XXVI

COLLECTING AND TABULATING DATA

The general analysis and survey puts the time-study man into a position to collect data with the minimum amount of wasted effort. During the analysis, he should have formed a clear idea of what data it is necessary to secure. He has taken steps, as a result of the general survey, to have all bad conditions corrected. Such changes as the management is willing to make have therefore already been made, and other changes must wait until funds, time, or opportunity bring about a more propitious occasion. There is now nothing else to be done before the actual gathering together of time studies is begun. As has been said before, analysis continues throughout the construction of the formula, but it is interwoven with other steps of the work.

Collecting of Studies Available.—Wherever incentive plans are used, there are usually several time studies which were taken to establish the existing time values and which will be of use as data for formulas. After the time-study man has made his general analysis and survey, he should select from the time-study files all studies which apply to the work to be covered by the formula. Quite often there are sufficient studies available to furnish all the data required, but unless a good portion of them were taken by the man who is making the formula, it will be advisable for him to take a few, the number depending on the complexity and variation in the work, so that he will be better able to use intelligent judgment in his analysis, classification, and selection of values. The studies which are available may have been collected over a comparatively long period of time. In this event, it is probable that conditions, methods, or equipment have changed, and unless the information on the back of the time studies is complete and definite, it will be better if the studies are not used except for comparison purposes.

Where the studies available are satisfactory in every respect, they will be a great help in several ways. They will shorten the time required to collect data, they will cover a more satisfactory

period of time, and they will generally cover a larger number of operators and a greater variety of jobs.

Taking New Time Studies.—If there are no studies available which are satisfactory for formula compilation, the time-study man should concentrate his attention on studying representative jobs until he has collected sufficient data. By representative jobs is meant types of work having characteristics similar to those of the work which will be covered by the formula. For instance, in studying the sawing to shape of composition material on band saws, it will be found that there are a number of jobs upon which only straight cuts aided by guides are taken. On others, straight cuts guided by templates are taken, and on still others radii are cut either by template or from layout. A number of jobs will be studied in each class which embrace the general characteristics of that class. Parts varying widely in size, shape, and thickness of material will be studied to insure the collecting of sufficient data to determine intelligently the amount by which these variable characteristics affect cutting time.

The number of studies which should be taken depends upon the nature of the work. Nothing should be left to judgment alone but rather all conclusions should be based on actual data and facts. If all jobs are very nearly alike, only a few studies need be taken, while on the other hand, if the work ranges widely in its variable characteristics, it will be necessary to take more. In general, the greater the amount of data collected, the easier it will be to determine constants and variables correctly and the more accurate will be the formula. Three points taken from data collected on jobs which vary widely in the characteristics being studied are the minimum number through which a curve should be plotted, but more are highly desirable. If only three points are used, one "wild" value may seriously alter the shape of the curve, whereas if more points are available, values that are incorrect will be easily detected and discarded.

In taking the studies, the time-study man should be careful to split up the operation into its elements in accordance with the division of elements which he has previously decided is the best to use. Too much stress cannot be placed on this point, for if the same division of elements is used throughout the studies, the subsequent derivation of the formula will be comparatively easy, and the results accurate and reliable.

It is always a good thing to study a number of operators during the course of collecting data instead of picking out one or two good men and basing everything on them. By studying a number of operators of varying skill and leveling all to the average man, more confidence will be instilled into the workmen who will work under the formula. It will also prevent any claims that all values are based on the best men and ideal conditions.

The procedure used in taking time studies for the purpose of compiling a formula is exactly the same as that used in taking studies to set individual time values. This has been set forth in detail in the first part of this book, and no further elaboration is here needed.

Accuracy, which is at all times important, is especially so when collecting data upon which a formula is to be based. If an error is made when taking a study from which an individual time value is to be set, only that value is affected, and the seriousness of the consequences depends upon the magnitude of the error and the activity of the job. If an error is made when data for formula use are being collected, every value set from that formula will be affected. Even a small error may assume serious proportions when it affects every job on a given class of work. Therefore, the time-study man cannot be too careful in collecting and working up his data, and every minute spent in checking up the accuracy of his work will be time profitably spent.

The number of pieces studied on any job depends, of course, on the nature of the work. Care should be taken to study enough to insure that the resulting values are representative. Formulas which are based on studies made on one or two pieces are generally inaccurate and subject to much criticism. On some lines of work where the operation cycle is unusually long and where the work comes through the shop in small quantities, it is impossible to get more than a few pieces on any job. In such cases, more jobs should be studied. When the time studies are later lined up on the Master Table of Detail Time Studies, it will then be possible to recognize unrepresentative time values because of their variation from the majority of the other values.

Collecting Data for Allowances.—The allowances which are given to care for fatigue, personal necessities, and unavoidable delays are the same for formula work as they are for individual time studies. The manner in which these allowances are determined has already been given in Chap. XX. Special allow-

ances, however, are used more in formula work than on work where time values are established by time study, usually because a more thorough study of existing conditions is made when collecting data for formulas. Three general classes of operations are commonly covered by special allowances in compiling a formula: work which occurs periodically and which is usually done as day work, work which occurs intermittently and irregularly, and work which could be handled by definite values in the formula but which would so complicate the formula expression that the labor involved in establishing time values would not be offset by the accuracy gained.

In some cases all three classes of special allowances are used in the same formula. A good example of this is found in a formula covering machine core making. An operation which occurs periodically is cleaning sand out of the machine at night and refilling and oiling the machine in the morning. This was formerly done as day work. The amount of time spent in 1 week on this work was determined by time study, and it was a simple matter to distribute this time over each time value by increasing formula values by the percentage of cleaning and oiling time to productive time.

After the cores are made, they are dried on a continuous conveyor oven. It is quite possible definitely to determine handling time for each core to and from this oven, both before and after blackening, but it involves the introduction of so many terms into the final formula that it is far easier and nearly as accurate to handle the small amount of time involved by a percentage figure. Before blackening, it is necessary to file off any fins that may be on the cores and to fill up any irregularities with black lead paste. Many things such as the nature of the core, the condition of the core box, the skill of the operator, and the use of the finished casting affect this smoothing time. It is practically impossible to express this time other than by a percentage figure determined by a series of all-day studies covering a wide range of work. In such cases as these, it is perfectly proper to establish special allowances. Care must be taken not to carry this practice to extremes and not to use allowances where the accuracy of the time values will be seriously affected. It is important that all special allowances should be determined by comprehensive studies and not merely determined by an estimate.

Recording Information.—Complete identifying information of each job studied should be recorded on the back of the time-study sheet. Good practice recommends that this should be done even though the study is to be used only for setting a single time value. In such cases, however, the details of the job are fresh in the mind of the time-study man, and he may be well able to set the time value without referring to any recorded information. For the purpose of establishing individual time values, then, complete information is not absolutely essential, although its lack renders the study valueless for future reference.

Time studies that are to be used for formula compilation may be taken several months before they are so used. Therefore their subsequent value is directly proportional to the completeness of the recorded descriptive data. A record of the drawing number, pattern number, or other shop identification makes it possible to locate the job if at any future time it is desired to check data already taken or to secure information which had been previously overlooked. A clear description of any unusual features which occurred during the taking of the time study will aid in explaining unexpected variations in the data.

It is absolutely necessary to have a complete sketch of the part and a complete record of all dimensions. Variable time elements will depend on variable job characteristics, and in order to determine the nature and magnitude of the variation, the time-study man must have sufficient data. If it is not given by the dimensioned sketch, he will have to refer to the engineer's drawing of the job.

Tool, jig, and fixture information should be given in detail. Sketches showing the manner in which the operation was performed such as Figs. 100 and 101 will prove helpful when working up the formula. In brief, it may be said that a description of everything having to do with the job itself and with the method of performing the operation should be completely and clearly recorded on the back of the time-study sheet at the time the study is taken.

Review and Correlation.—When the time-study man feels that he has collected sufficient data, he will find it very profitable to spend a few days watching the performance of the work without actually taking any studies. During the time he has been making the studies, his attention has of necessity been concentrated on each job that he studied. He has had little chance to

view the work as a whole, and it is quite possible that important considerations have hitherto escaped his attention. Through his time-study work, he has gained an intimate knowledge of the work which he did not possess before. Thus he is in a good position to review what he has learned and to see just exactly what must be done to perform the work successfully.

While he is watching the work and making what may be called a mental synthesis, he will have ample opportunity to talk with the foreman, workmen, and others who are familiar with the details of the work. He will, without being aware of it at the time, secure much information which will later be of value to him. The reasons for everything which is done should be readily apparent to him, and he will gain a more intimate knowledge of existing conditions.

The amount of time which should be spent on this phase of the work will depend on the complexity of the operation and upon the familiarity of the time-study man with the work. When he finishes the review and correlation, he should feel thoroughly familiar with all of the details of the work and he should have gained, in a general way, an idea of the form of the final formula.

Master Table of Detail Time Studies.—Reference has been made several times to the Master Table of Detail Time Studies. Before passing on to the tabulation of data, it will be well to give a brief description of this important form. A Master Table compiled for a sample formula is shown in Fig. 139. It is 22 by 17 inches in size. When folded once in each direction, it may be conveniently filed with standard $8\frac{1}{2}$- by 11-inch papers.

In the upper left-hand corner, space is provided for identifying the sheet to the formula. Experience in trying to locate unidentified Master Tables will prove the value of completely filling in this part of the form. Under this space is a wide column headed Operation Description. Here will be recorded the name of each elemental operation. The columns to the right under *S*-1, *S*-2, and so on are used for recording the time data taken from time studies. The top part of these columns is devoted to a description of the characteristics of each job.

The purpose of this form is to enable the time-study man to tabulate his data so that they will be convenient for the analyzing of each elemental operation. He has before him the characteristics of each job and the time for performing each elemental operation on each job. He can see at a glance which operations

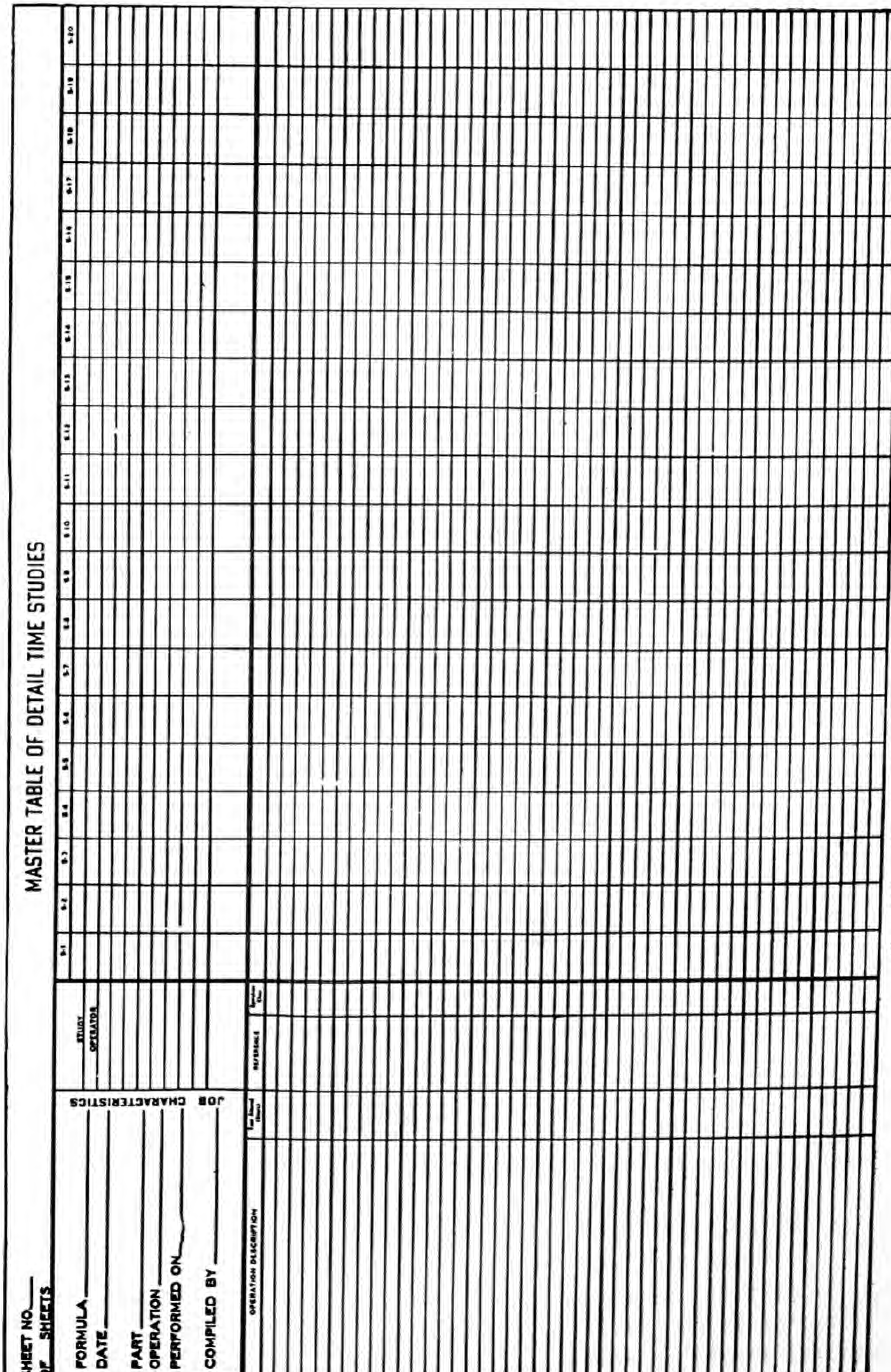
are performed on every job and those which are performed only in special cases. He will easily be able to review the time taken to perform a certain operation on every job, and he will readily see whether that operation time is fairly constant or not. If the attempt were made to use the data which have been collected directly from the time-study forms upon which they are recorded, the work of compiling the formula would be increased many times and the final accuracy would be seriously affected.

Posting Data on Master Table of Detail Time Studies.—All usable data should be posted on the Master Table of Detail Time Studies. Values which the time-study man is satisfied are incorrect and operations which are obviously unnecessary should not be posted. The tabulation should be made neatly and preferably in ink. Under Operation Description is recorded the name of each elemental operation. The space set aside for Job Characteristics should show the date upon which the study was taken, the name of the operator studied, and a complete record of job identification and variable job characteristics. On some classes of work, a small neat sketch of the part may be made at the bottom of the Job Characteristic space.

In the Elapsed Time columns is posted the leveled time value with allowances added for each elemental operation for each time study. Thus a vertical column in connection with the Operation Description is a list of the time values which occurred in one particular study. A horizontal line is a list of the time values which occurred on every time study for one particular elemental operation.

It is not necessary to list the elements in the order of their occurrence. When the first study is posted, the elements will be tabulated as they occur. For the succeeding studies, whenever an element occurs that occurred in the first study, the time value is posted opposite the corresponding operation description. Otherwise the name of the element must be given a separate line.

The columns headed Symbol, Allowed Time, and Reference are filled out when the allowed time is determined. Each elemental operation should be given an alphabetical symbol. These symbols should be assigned as nearly as possible in the order in which the elements occur. As each constant allowed time is determined, it should be recorded in the Allowed Time column, and the study or studies in which the selected value occurred should be noted under Reference. If the operation is a


MASTER TABLE OF DETAIL TIME STUDIES

SHEET NO.____
OF ____ SHEETS

FORMULA ____
DATE ____
PART ____
OPERATION ____
PERFORMED ON ____
COMPILED BY ____

JOB CHARACTERISTICS

STUDY
OPERATOR

OPERATION DESCRIPTION

REFERENCE

S-1 S-2 S-3 S-4 S-5 S-6 S-7 S-8 S-9 S-10 S-11 S-12 S-13 S-14 S-15 S-16 S-17 S-18 S-19 S-20

Fig. 120.—Master table of detail time studies.

variable, the curve or table which handles it should be recorded. If there are more than 26 elemental operations, the alphabet may be repeated with subscript numbers as A_1, B_1, and so on.

At the extreme upper left-hand corner the following heading will be noticed:

Sheet——
of——sheets.

This should be filled out to read as Sheet 1 of 3 sheets if more than one Master Table form is used. Thus if referring to the Master Table at any future period, one may be sure that he has all of the sheets that were used.

The actual work of posting is simple enough to delegate to a clerk working under the supervision of the time-study man. Like everything else connected with time-study and formula work, it must be done accurately, and the figures posted on the Master Table should be carefully checked before going ahead with the formula compilation.

CHAPTER XXVII

CLASSIFYING OPERATIONS AND DETERMINING CONSTANTS AND VARIABLES

When all time values have been posted from the time studies to the Master Table, the time-study man is ready to choose values which will be used in the final formula. As has been mentioned before, there are two general classes of elemental operations; first, those operations which are exactly the same regardless of the characteristics of the job and, second, those which vary in method or time of performance with variable job characteristics. In many cases, it is fairly easy to determine whether or not an elemental operation is a constant. In others, there will be a wide variation of the time taken for doing the operation on different jobs, and the reason for this variation may be somewhat obscure. Considerable analytical and mathematical ability is necessary to trace the reason for such a variation to its source and to determine exactly how the time required for performing the operation is affected.

Preliminary Analysis.—Before actually classifying elemental operations as constants or variables, a preliminary analysis of the data on hand should be made. It is well to note if a representative number of operators who are engaged in performing the class of work under consideration have been studied. Theoretically, it should be possible to arrive at the same results if only one or two men are studied, since the use of the leveling principle brings all time values to the plane of the average man. If the time-study man is an expert and is thoroughly familiar with the work, he will no doubt be able to do this, but actually it is better to study a number of different operators. Not only will the time-study man thus have a check on his judgment and upon methods employed in doing the work, but he will also find it much easier to convince supervisors and workers that his time values are truly representative.

If the data collected on an ordinary simple operation extend over several sheets of Master Tables and if the same elements

appear to be repeated on only a few of the different jobs, it is reasonably certain that the time-study man did not divide the major operation into its elements in the same manner for the various studies. If such be the case, it is rather difficult to get the data into usable shape. By dint of combinations, subtractions, and simultaneous equations, it may be possible to resolve the data into a more compact form, but unless these data appear to be fairly consistent for the different jobs, it is better to throw away all that has been done and make a fresh start aided by the experience gained. Such cases happen usually only when a new time-study man is making his first formula. Thereafter, he has a better idea of the form that final data should assume, and he chooses his elemental operations accordingly.

A good set of data should have a compact appearance on the Master Table. There will probably be some few operations that were performed on only one or two jobs and there will be others that occur only on jobs having certain characteristics, but for the majority of operations a time value should appear on each study.

Classifying Operations into Constants and Variables.—The time-study man is now ready to review each elemental operation separately and to determine whether it is a constant or a variable. Pure analysis will generally be sufficient to tell an experienced time-study man whether or not an operation should be constant on all jobs, but he should also be guided by the data. If analysis shows that an operation should be constant and if the time values appear to be of the same magnitude with only a slight variation between the minimum and the maximum, then it is safe to classify that operation as a constant. Similarly if there is a wide range between the minimum and the maximum time values on an operation which analysis shows should be variable, it is again proper to classify the operation accordingly. It is only in those cases where analysis and the data do not lead to the same conclusions that the time-study man need hesitate. He will usually find an unexpected variation in the time taken for doing an element which he expected to be a constant rather than the opposite. He will find it necessary to review his time studies in order to find out the reasons for an unexpectedly high or low value. If he can find no satisfactory explanation, he must observe the operation as it is being performed and perhaps even make additional time studies. In the end after he has collected

sufficient data and has given sufficient thought to them, the time-study man will practically always reach a satisfactory conclusion as to the nature of the operation.

As each operation is classified, it should be marked with a small *c* or *v* to identify it definitely as a constant or a variable in the future. Miscellaneous operations which occur only once or twice throughout all the studies should be marked with an *m* and left for consideration until after the magnitude of the constant and variable operations has been determined.

Choosing Constants.—After the elements have been classified into constants and variables, a time value must be selected for each element that has been recognized as a constant. The values obtained from the several studies for a given element may vary considerably, often as much as 100 per cent. This is because of errors in judgment on the part of the time-study man as to the skill and effort displayed by the operator, variations in conditions under which the work was done, differences in the efficiency of the machines, and so on.

In order to make an intelligent selection, the time-study man must know the actual conditions under which the job was worked, he must know the ability of each operator intimately, and he should be acquainted with the equipment and the kind and condition of all materials used. All time studies that do not give fully this information should be used only as a means of comparison. If the time-study man knows all that is necessary, he will be able to make a selection from the several elements listed on the Master Table. Beginning at the left-hand side of the table, he will run over to the right carefully, comparing each value with the others and mentally noting the conditions under which the value was obtained. After having carefully studied and compared them, he will make his selection. The selection should be the time in which an average man engaged on this line of work can perform the given element working at an average rate of speed with average working conditions. When the value has been selected, it will be recorded in the column provided on the Master Table together with the number of the study from which the value was selected.

The value which is chosen snould be, where possible, one which occurs several times on different studies and which is about midway between the minimum and maximum values. If sufficient data have been carefully collected, such values will be found

in the majority of cases. Where there is an unexplainably large variation and where no value is repeated in two or more studies, all values should be averaged, and the actual value which is closest to this average value should be used. Actual values should be used rather than average because of the psychological effect on those to whom the formula must later be sold and to facilitate reference.

Analysis of Variables.—Choosing constants is a comparatively simple matter, but the determination of variables requires keen judgment and good analytical ability coupled with a knowledge of algebra and the principles of curve plotting. In this phase of time study and formula work, the technically trained man usually outstrips the practical man because of his familiarity with various mathematical devices.

Each variable element must be considered separately and the means of handling it determined to fit the individual case. Probably the simplest way of handling variables is to divide the work as a whole into several classes and to select a constant value for each class. For example, the time required to lift a part from a tote pan to the table of a drill press is found to vary in a general way with the size of the part. In this case, sufficient accuracy will be obtained if the work is classified as small, medium, and large, and if three values are selected from the data, one for each class. If the drill-press work covers a very wide range of sizes, it may be necessary to add two more classes, such as very small and very large. The time-study man in making this classification will determine the approximate limits of weight and volume for each class and will include them in the final formula report as a guide to those who will apply the formula in the future.

Similar classifications may be made for operations upon which time varies with the complexity of the job. It will be noticed that the work covered by the molding formula in Chap. XXXV has been classified as simple, medium, and complex and that definitions of the characteristics pertaining to each class have been given.

Expressing Variables in Curve Form.—Variables are probably expressed more conveniently in curve form than in any other way. Indeed, the time-study man will find the plotting of curves a great help during his analysis of variables regardless of how he decides to handle the element in the final formula.

The variable job characteristic with which the time for performing a certain operation varies is not always readily apparent. In such cases, a series of experimental curves should be plotted to show how time varies with each variable characteristic which would be likely to affect it. On one curve, the points will probably line up better than on any other, and if analysis does not point to the contrary, it may be safely assumed that this is the proper relation to use.

Points for curves plotted on such things as machine time will usually line up very nicely and definitely mark the proper direc-

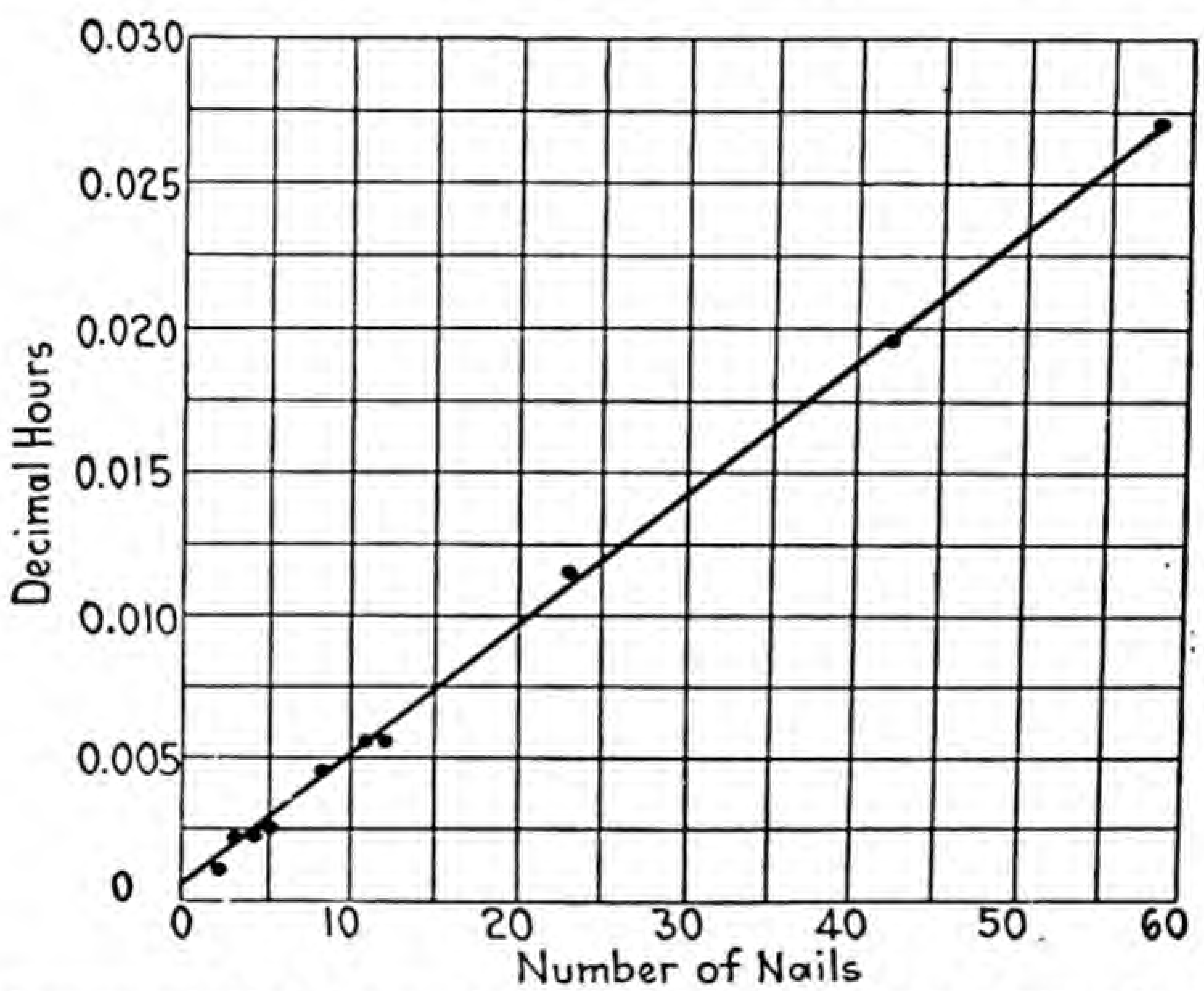


Fig. 121.—Curve plotted from data collected on time required to set nails—point down.

tion of the curve. Points plotted on operations which are largely affected by human skill and effort will more often show a wide range, and a technically trained man making his first formula is quite likely to feel rather discouraged when he tries to plot his data. If he will stop to consider how many minute things practically impossible of detection may affect the time taken and if he realizes that skill and effort range in a series of infinitesimally small steps from a minimum to a maximum whereas the leveling method only recognizes six classes for practical purposes, he will not wonder that such data do not plot up as smoothly as a speed-torque curve or a load-efficiency curve. Data secured on human effort will if properly obtained plot up

well enough to show definitely the trend of the curve, and the time-study man, aided by judgment, will be able to draw what will be a very nearly correct curve.

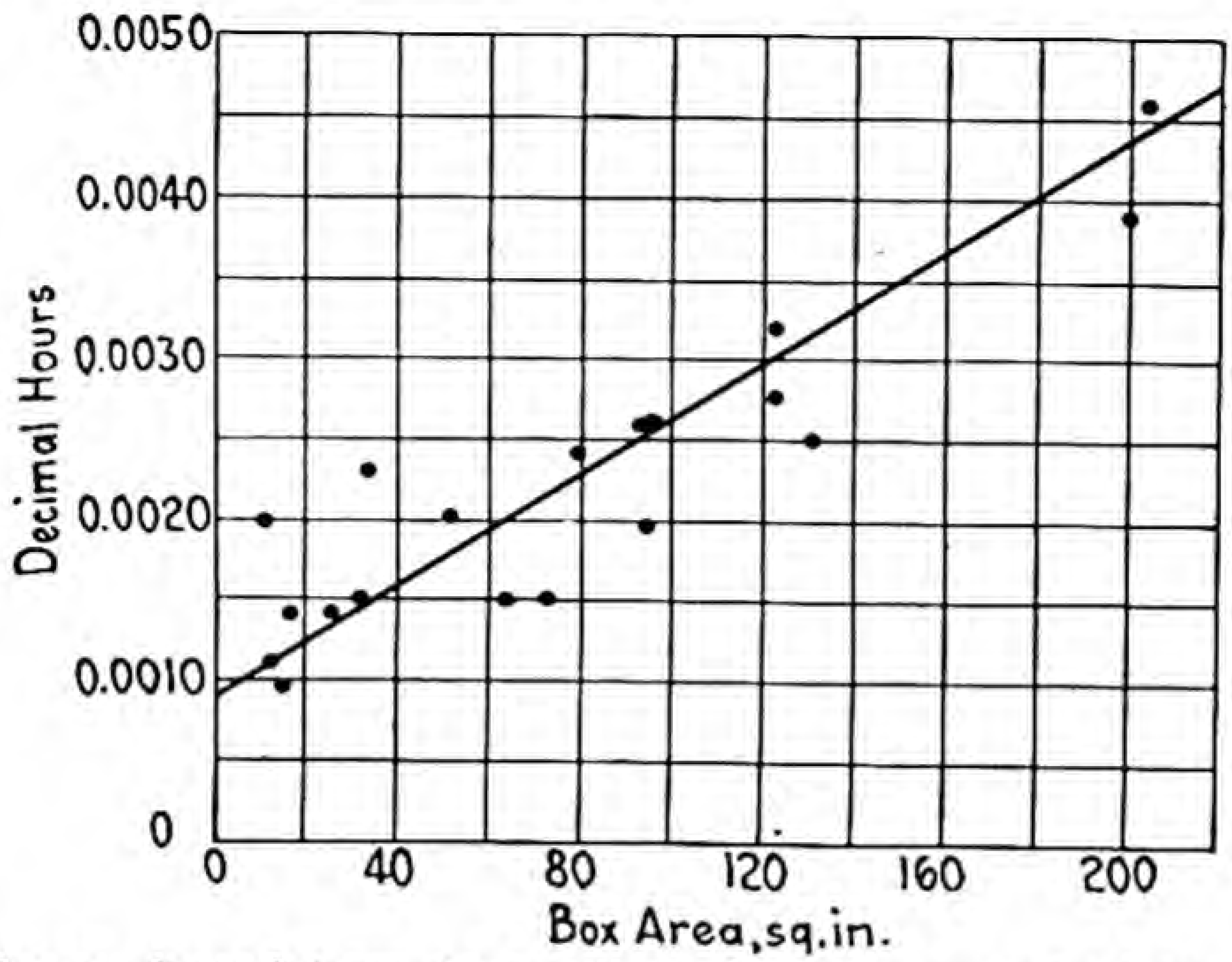


FIG. 122.—Curve plotted from data collected on time required to place box on table.

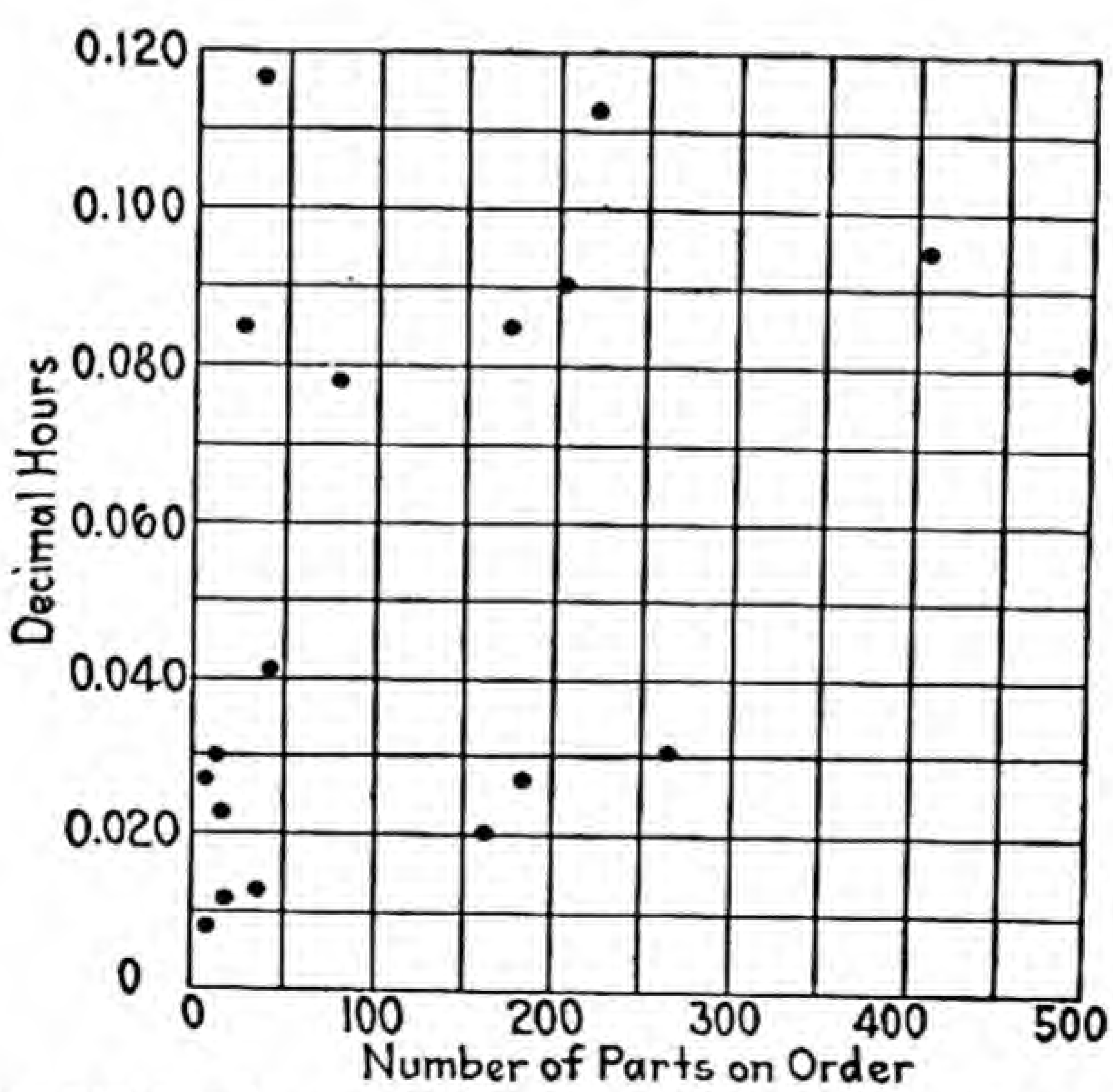


FIG. 123.—Points plotted from data collected on time required to draw material from bin.

The curve of nailing time against number of nails shown in Fig. 121 shows about as good a set of points as may be expected.

More often points will appear as shown in Fig. 122. The variation here is not too great, however, to show definitely the trend of the curve. The points shown in Fig. 123 are dotted all over the paper and prove conclusively that the time required for performing the operation of "draw material from bin" in a storeroom does not vary with the number of pieces on the order.

Expressing a Relation between Three Interdependent Variables.—The time-study man will very often find that the time for performing a certain elemental operation is affected by two variable job characteristics, and it will be necessary to take them

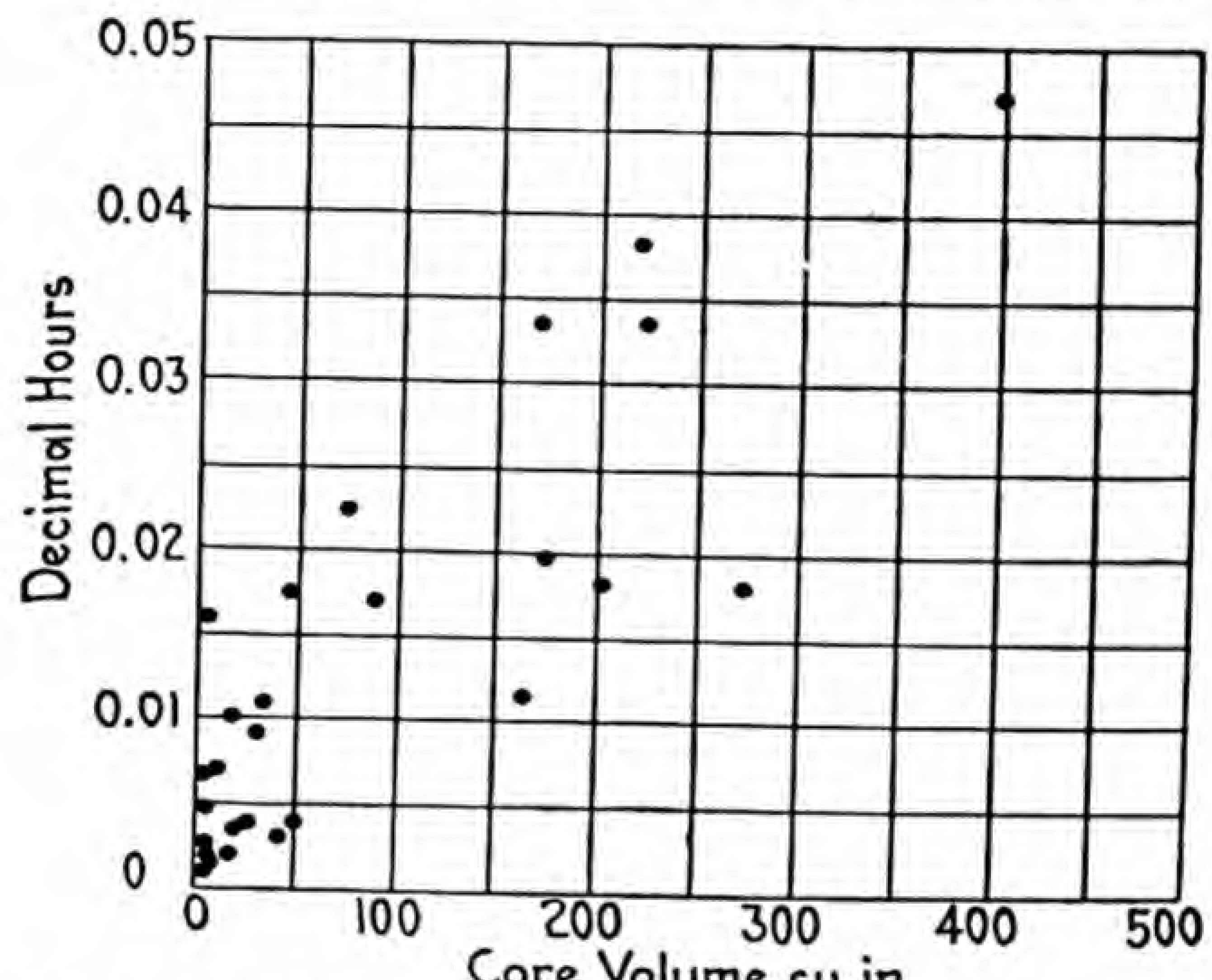


FIG. 124.—Points plotted from data collected on time required to fill core box with sand and peen—core volume in cubic inches *vs.* decimal hours.

both into account in some manner. The simplest way is to classify one of the variables as small, medium, or large, or smooth surfaces and rough surfaces, and then plot the other variable against time for each class. This method is perfectly satisfactory in some cases, but where greater accuracy is necessary, another way must be found.

A definite example may show how a case of this kind should be handled. For the elemental operation of "fill core box with sand and peen," analysis at once showed that filling and peening time should vary with the volume of sand handled. Accordingly points were plotted volume against time as shown in Fig. 124. It was apparent at a glance that some other factor entered in. Further analysis revealed that the relation between the height and the thickness of the core would also affect the time. Where

the thickness of the core is great in comparison to the height, all sand may be put into the box and peened at one time. Where the thickness of the core is small as compared with the height, sand must be put in a little at a time and peened frequently. It is evident then that the ratio of height to thickness affects filling and peening time as well as core volume. An attempt was then made to classify the work according to this ratio, plotting a curve for ratios up to one, another for ratios between one and two and so on. The results were unsatisfactory and this method was abandoned.

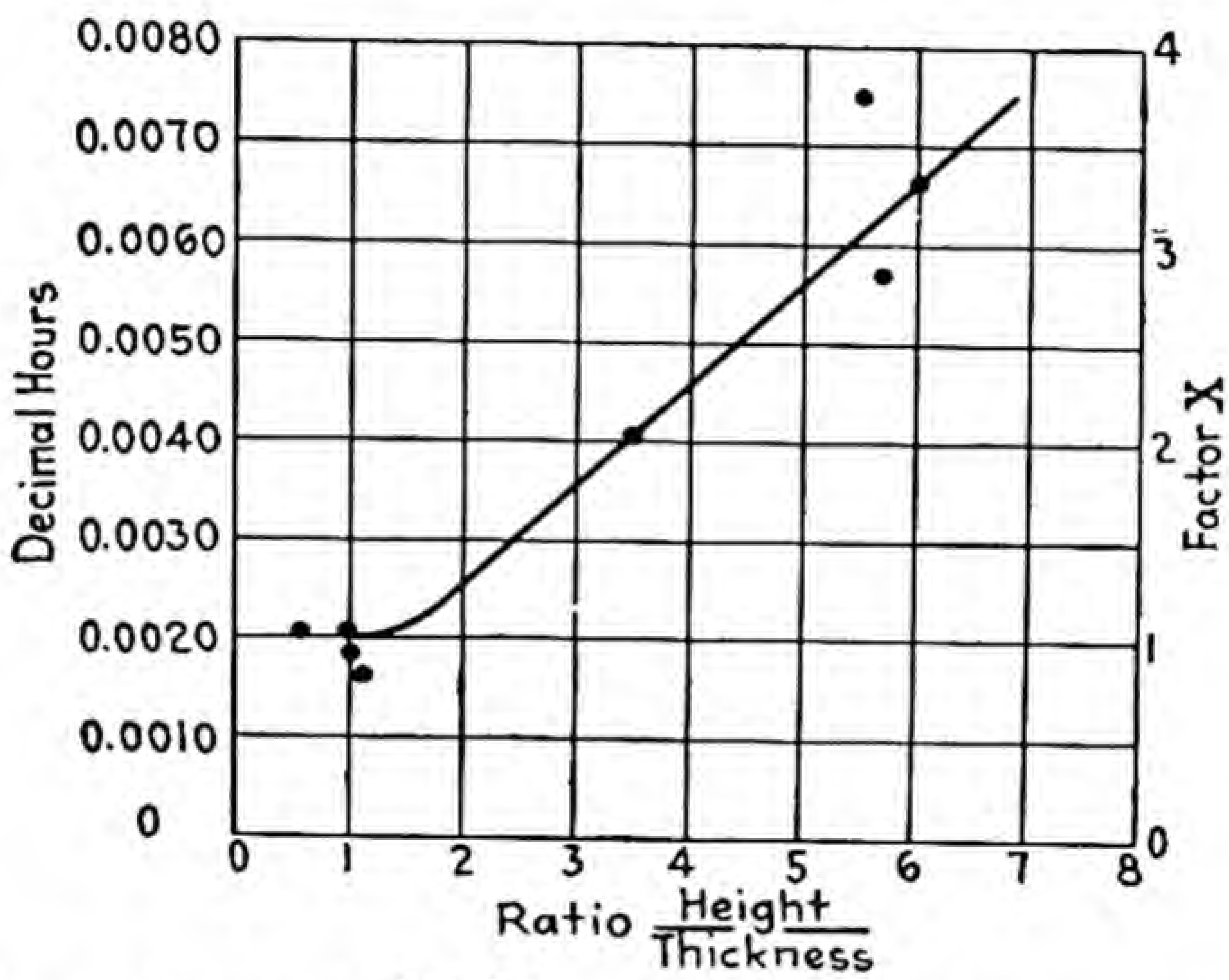


FIG. 125.—Curve of ratio of $\frac{\text{height}}{\text{thickness}}$ *vs.* decimal hours for cores of from 5 to 10 cubic inches volume for operation "fill core box with sand and peen."

It was finally determined to use two curves in conjunction with each other. A curve of time against ratio of height to thickness was plotted for cores having an approximately constant volume. Since volume was constant, the curve showed a true relation unaffected by volume. This curve was plotted as shown in Fig. 125. It will be noticed that the curve intercepts the Y axis at 0.0020 hour. The time scale was changed by calling this point of interception 1, the point at which the time doubled or 0.0040 hour 2, and so on. Then in order to get a curve of volume against time unaffected by the height and thickness of the core, each time value taken from the original data was divided by a factor determined by the ratio of height to thickness of the core and read on the new factor X scale as shown in Fig. 125. These values plotted against the corresponding volumes

give a time-volume curve unaffected by the height and thickness of the core. The points now lined up into two sets of points as

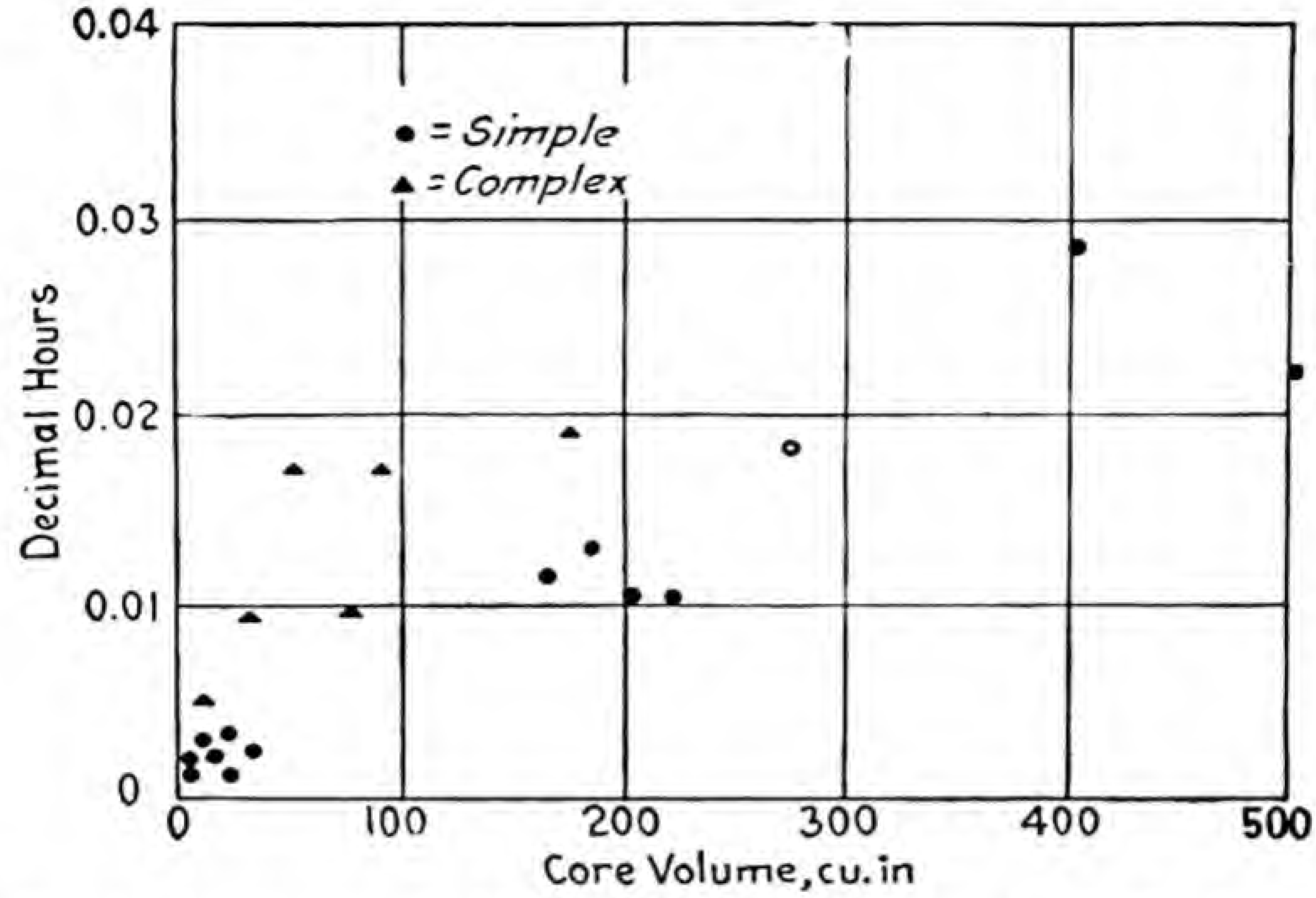


FIG. 126.—Points shown in Fig. 124 when corrected for effect of ratio of $\frac{\text{height}}{\text{thickness}}$ of core for operation "fill core box with sand and peen."

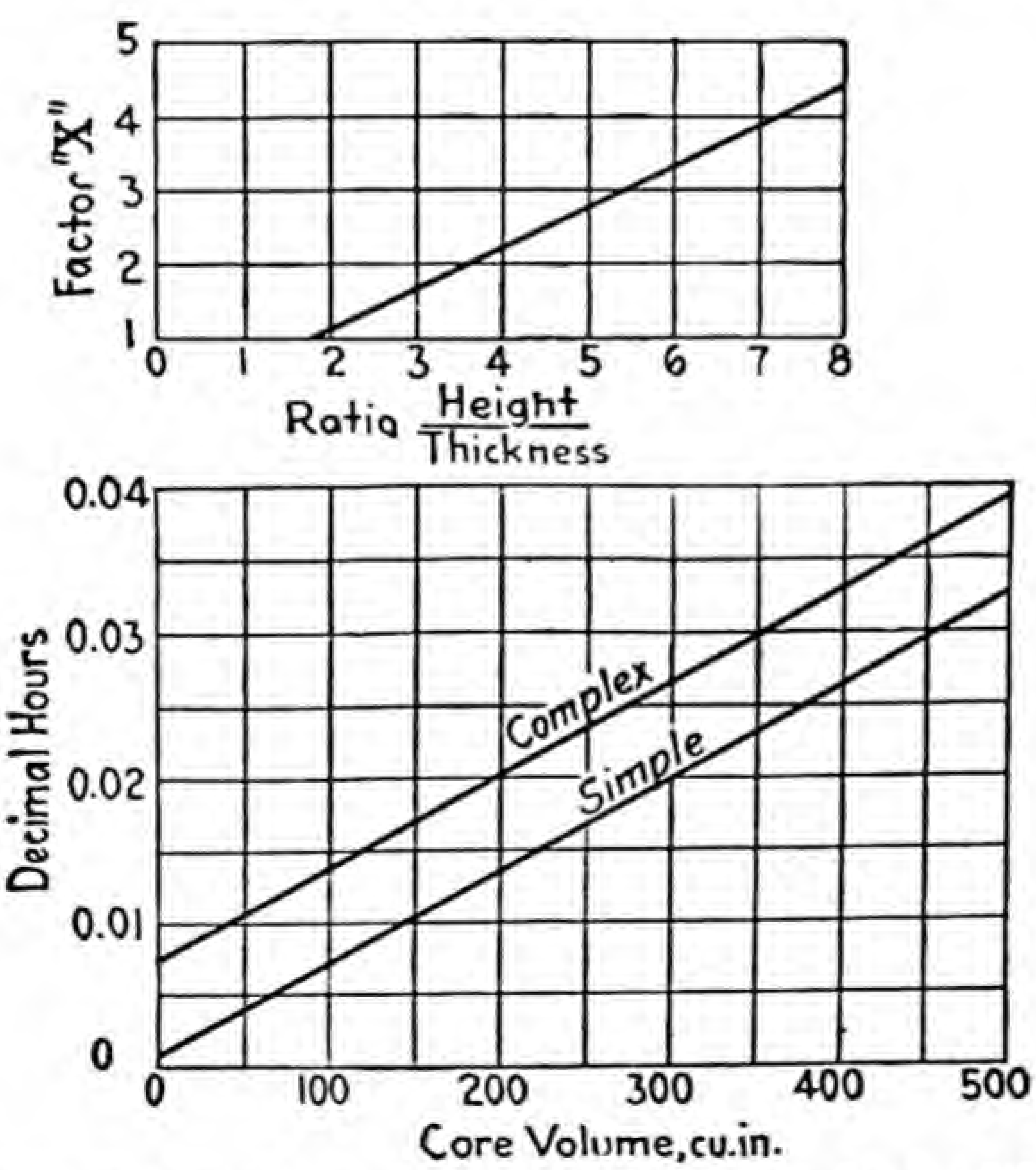


FIG. 127.—Final curve sheet for operation "fill core box with sand and peen."

shown in Fig. 126. A little further study of the data showed that the higher values were all obtained from studies on cores which were difficult to make. A further classification of jobs as simple

or complex enabled the plotting of the final curves shown in Fig. 127.

In order to arrive at filling and peening time for any core, a factor X is found corresponding to the ratio of the height and thickness of the core and a base time for the proper volume from the volume-time curve. These two values multiplied together give the true time required for filling and peening. For example, a simple core having a ratio of height to thickness of 4.2 and a volume of 130 cubic inches would receive an allowed time value for filling and peening of $2.4 \times 0.0092 = 0.0221$ hour.

Miscellaneous Values.—In practically every set of data compiled into a Master Table of Detail Time Studies, a few elemental operations will appear which were performed on only one or two studies. In many cases, these operations were entirely legitimate and were made necessary by some special characteristic of the particular job. At the time of classifying operations, these elements were classified as miscellaneous and marked with a small m.

The way to include these miscellaneous elemental operations in the formula expression depends upon the nature of the operations. If an operation is caused by a variation in material such as removing a piece of metal left by a defective core from a casting, it is likely to occur at any time. Here it is best to determine the amount of time spent on such operations over a representative period of time and to express it as a percentage of the total time spent. Then the time for every job done under the formula is increased by the determined percentage. This practice simplifies the formula and tends towards consistency and is recommended where accuracy is not too greatly sacrificed.

Certain other operations will be found to be made necessary by a certain characteristic of the job being worked. This variable characteristic may occur on only a very small proportion of the total jobs. Therefore, in order to simplify the formula expression, it is best to include such time values in a table of Miscellaneous Values. Complete instructions about the manner of applying these miscellaneous values should accompany the formula.

The selection of a proper time value for a miscellaneous operation requires more care than if the operation were done on every

job, because there are generally but one or two values to choose from. The time-study man must review the studies from which these values were taken, and use good judgment in deciding whether or not the operation was properly performed. If there is any question of doubt about the correctness of the time value, it is best to place only the operation name in the table of Miscellaneous Values and leave the space for the time value blank until such time as the operation may have been thoroughly checked. This may not be until after the formula has been in use for some little time, since these operations occur but rarely.

Element Analysis.—A complete record of the reasoning and deductions of the time-study man in the classifying of operations, choosing of constants, and the establishing of variables, curves, tables, and the like, will be found to be very valuable. This record is known as the Element Analysis. In the element analysis, each element is analyzed carefully and completely. If it happens to be a constant, an explanation of why this is so is given. The selected values for all constants, considered separately, are explained and justified. The derivation of the curve or table for each variable element should be given and its basis justified. Every step and thought which led to the final result should be carefully recorded. If in plotting a curve different factors or characteristics from those finally adopted were tried and found to be unsatisfactory, it should be explained in the element analysis in detail. The value of such an analysis is obvious, for should it become necessary to investigate or revise a formula at any time, a review of the element analysis will give the time-study man who made the formula or any other time-study man a complete knowledge of how the formula was derived and the reasons for each elemental value. Chapter XXXIII shows a complete element analysis.

CHAPTER XXVIII

FORMULA EXPRESSION

The formula expression is the result of all the work which has been done in the making of the formula. The first thing which was done was to collect data, the next was to analyze and classify them into constants and variables, and the next was to build up the values or to compile them into the formula. The building up of the values is done by synthesis, after which the expression is formed. The formula expression should be in the simplest possible form. Every value should be reduced to the simplest terms. It should not be the aim to make an imposing or a complicated expression, but rather to keep in mind the time which will be required to apply the formula. The routine man who uses the formula is usually a busy man, and if the formula takes what in his mind is too much time, he will short cut much of it and will probably establish many inconsistent values. The purpose and the meaning of every term in the expression should be readily understandable without referring to the formula report, and every symbol should be clearly defined in brief terms.

If space does not permit a clear definition of how and when to use any of the values in the expression, it is sometimes necessary to write an instruction sheet or set of instructions which should explain clearly and fully how and when each value is allowed and also any explanation which is deemed necessary on how to compute them.

Combining Constants.—In order that the expression be in its simplest form consistent with accuracy and time required to compute, it is necessary that all values and symbols be combined where possible. This combining process is explained under Synthesis in the Formula Report, and reference to Synthesis should show every step in the combining process. All possible combinations should be made in the building up of the formula. For example, take a simple operation, say drilling, tapping, and countersinking holes on a drill press. The formula from which the tapping time is determined will probably cover other opera-

tions such as reaming, burring, counterboring, and the like. The formula expression will contain a constant, which will be the sum of all elemental operations which occur on every drill-press operation, plus a term for drilling which considers the size of hole, the thickness of part to be drilled, and the material, and which is multiplied by the number of holes, plus a similar term for countersinking, plus a tapping term which takes into account the size of tap and the depth threaded, and other terms which cover additional handling operations. Any one of these terms is made up of several elemental time values, and the time value which is finally established is the sum of the appropriate terms multiplied by the number of occurrences.

The elemental operations may be classified as part handling, machine handling, and machining. Under part handling will be grouped such values as "pick up part," "place in vise and tighten," "loosen vise and remove part," and "lay part aside." It is apparent that these operations will occur once on each piece. Instead, therefore, of having the time for each element in the expression, the time values allowed will be added together, and one value which will take care of the constant part-handling time for vise jobs will be given in the formula expression.

Under machine handling will be grouped such elemental operations as "move to hole location," "lower spindle," "engage feed," "release feed," and "raise spindle." It is also apparent that these elements will occur once for each hole drilled and that the time must be allowed accordingly, but as in the case of part handling, it is not necessary to have in the expression the separate time for each element. The elemental times will be added together, and the total will be included in the formula expression as a single term and will be allowed once for each hole drilled. Here it is seen that one value takes the place of five. This same process of combining constants and symbols will be continued through to the completion of the expression.

It is possible to go on indefinitely with examples of combining constants, but it is not deemed necessary. The examples of formulas which are to follow will serve to illustrate how the values are combined. This point of combining for simplicity and ease of handling should be given a great deal of thought by those who are interested in formula work. The authors have had men who were not sufficiently grounded in the principles of formula construction turn in for approval formulas that were

far from being in the simplest form. After carefully analyzing the expression, it was possible to reduce its length considerably, often to half the number of terms, notwithstanding the fact that the time-study man believed that he had combined everything that should be combined.

Tables.—Certain kinds of data should be made up into tables and referred to in the formula expression by a single symbol. Tables serve to simplify the formula expression and to keep it from becoming unwieldy.

Tables of miscellaneous values have already been discussed. It is readily apparent that such values which occur but infrequently can be most conveniently handled in tabular form. The time values are thus always available when needed but need not be considered on the ordinary run of work. Additions may be made to the table of miscellaneous values whenever a representative time value for a miscellaneous operation is obtained. If these additions are made from time to time, the table will eventually become complete and will contain sufficient information to allow the establishing of all time values without the necessity of taking time studies. This, of course, refers only to work on which unusual operations may occur and for which the accuracy obtainable by a Table of Miscellaneous Values is desired. Some classes of work are so simple that no miscellaneous operations may ever occur. In other cases, miscellaneous values are so numerous that they are better covered by a percentage allowance.

Specific tables may be compiled to cover such operations as gaging. Checking and measuring the work may be done with pin, plug, ring, or snap gages or with calipers, micrometer or a scale. The gaging table will give the time allowance for each method of measuring. Similar tables may be compiled under specific heads such as a Reinforcing Table for core work or Table of Constant Machining Operations for lathe work.

Tables or charts giving time values for varying conditions of feeds and speeds may be conveniently used for machine work. An example of such a table has already been given in Fig. 99, Chap. XV.

In many cases, a relation may be expressed either by a curve or in tabular form. Figure 121 showed a curve of the time required to set nails against the number of nails set. This could also have been expressed as follows:

TABLE OF NAILING TIME

Number of nails	Nailing time	Number of nails	Nailing time	Number of nails	Nailing time
1	0.0011	21	0.0102	41	0.0193
2	0.0015	22	0.0106	42	0.0197
3	0.0020	23	0.0111	43	0.0202
4	0.0025	24	0.0115	44	0.0207
5	0.0029	25	0.0120	45	0.0211
6	0.0033	26	0.0125	46	0.0216
7	0.0038	27	0.0130	47	0.0220
8	0.0042	28	0.0134	48	0.0225
9	0.0047	29	0.0138	49	0.0229
10	0.0052	30	0.0143	50	0.0233
11	0.0056	31	0.0147	51	0.0238
12	0.0060	32	0.0152	52	0.0243
13	0.0065	33	0.0157	53	0.0247
14	0.0070	34	0.0161	54	0.0252
15	0.0075	35	0.0166	55	0.0257
16	0.0079	36	0.0170	56	0.0262
17	0.0083	37	0.0175	57	0.0266
18	0.0088	38	0.0179	58	0.0271
19	0.0092	39	0.0183	59	0.0275
20	0.0097	40	0.0188	60	0.0280

If the formula is to be applied by a man who has had little or no technical training, a table will be easier for him to handle than a curve. Tables offer less opportunity for error when used by an untrained man and thus permit the establishing of more consistent time values.

Most time-study men, however, are thoroughly familiar with curves and those who are not can be readily trained to use them. With a little practice, accuracy will be developed. Tables are, in general, more bulky than curves and often require interpolation. Where interpolation is required, the advantages enumerated above are lost.

Curves.—Curves plotted on rectilinear coordinate paper form about the simplest and most convenient means of expressing relations between variables. It is usually better to leave the curves in graphic form rather than to try to express the relation which they show algebraically. Many of the curves which are obtained in time-study work are straight-line curves. The mathematical ability needed to express such curves alge-

braically is not great, and where desirable, the curve may be reduced to algebraic form. In all other cases, unless there is a great advantage in having the algebraic expression, the graphic curve may be used satisfactorily.

Sometimes advantages result in plotting curves to logarithmic coordinates. Wherever this is the case, it is perfectly proper to use such coordinates. There are many excellent texts available on the handling of variable relations graphically which go more deeply into the subject than is possible or desirable in a book of this kind. It will suffice here merely to recommend the use of curves wherever a convenience or a saving in labor is to be gained. The examples which follow show clearly how curves are used in actual practice.

Graphic Charts.—Everyone who has had occasion to study or use steam charts realizes the great convenience which is gained by expressing the many variable relations graphically in one composite chart. The same convenience has been gained in many other lines and may well be applied to time-study work wherever practicable. Such charts will greatly aid in the quick and accurate solution of a formula expression. A good example of this is given in Chap. XXXV. Part of the formula expression, that is, $\frac{0.2959}{A} + 0.00234C + 0.0207P$, has been plotted in chart form for each classification of pattern as shown in Curves 1, 2, and 3 of the bench-molding formula. Values of A range from one to seven and of P from one to three. Thus 21 definite points are located on the chart from which curves representing C may be drawn. The ease with which the above expression may be solved is readily apparent.

Alignment Charts.—Alignment charts may be used to great advantage to multiply or divide two or more variable values. They are a great aid in computing time values which are affected by two variable job characteristics. In Chap. XXVII was shown the method of expressing such a relation graphically. The final curves shown in Fig. 127 may be put into alignment chart form as shown in Fig. 128, thus simplifying the computation of the time allowed for "fill core box with sand and peen." Instead of reading four scales and performing a multiplication, it is necessary only to locate the proper points on the two outside scales, connect them with a straight line, and read the time allowed directly on the middle scale.

Many more elaborate alignment charts have been made to cover the relations between time and feed, speed, depth of cut, and the like. A chart of this nature is shown in Fig. 129. The actual work involved in plotting such charts is not great. Com-

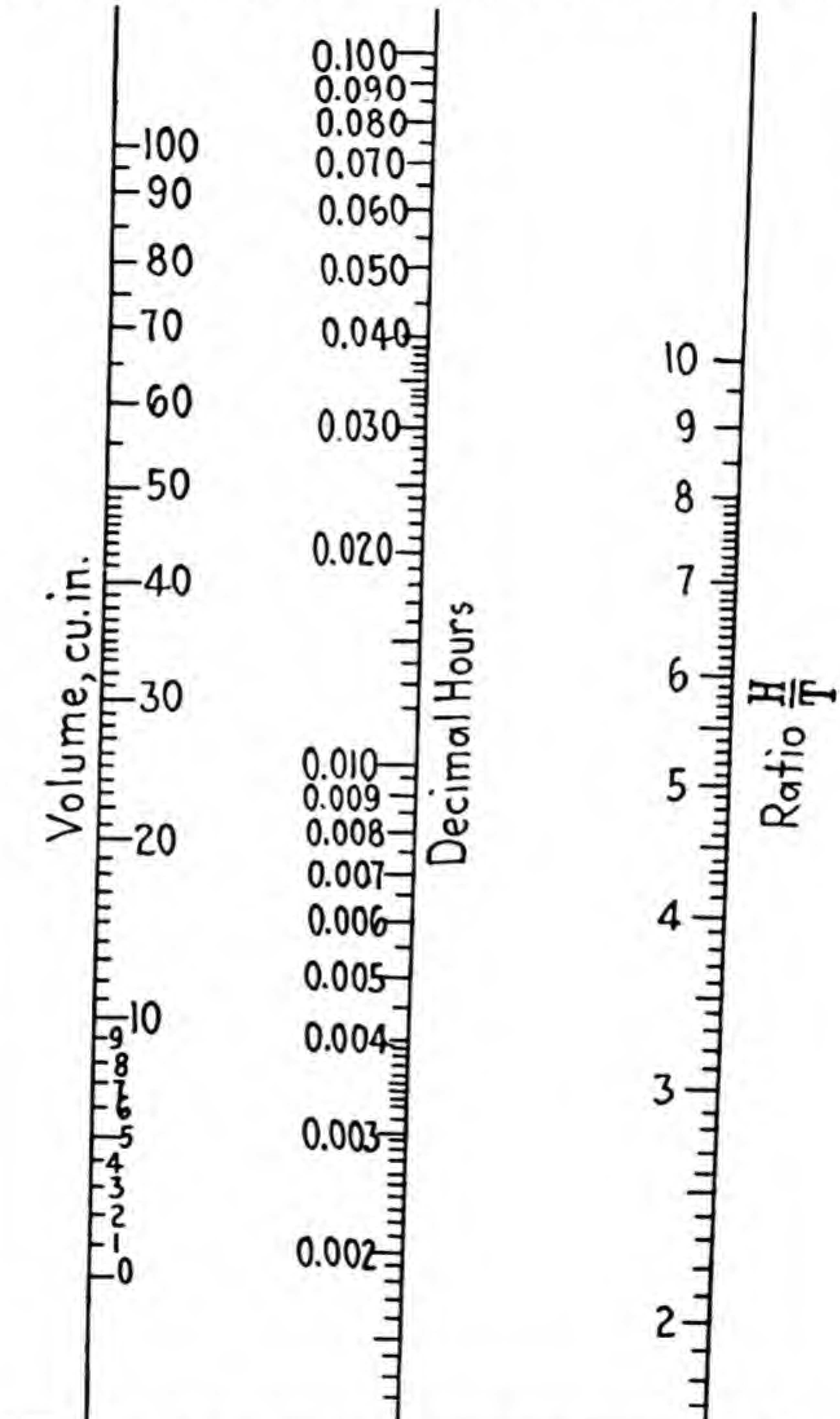


Fig. 128.—Alignment chart made for curves for simple core shown in Fig. 127.

plete texts covering methods of plotting alignment charts for many different conditions are available for reference.

The Final Expression.—When all constants have been combined and all charts, curves, and tables compiled, there remains only the task of placing them in the most convenient form for reference. The algebraic expression is usually entirely satis-

factory. It shows clearly all factors that must be considered, and it precludes the possibility of any omissions.

The constant which applies to every job, if such there be, should come first. Then follow other constants together with the symbols, which in connection with the symbol explanation, show when and how often each constant should be used. Lastly should follow references to tables and curves.

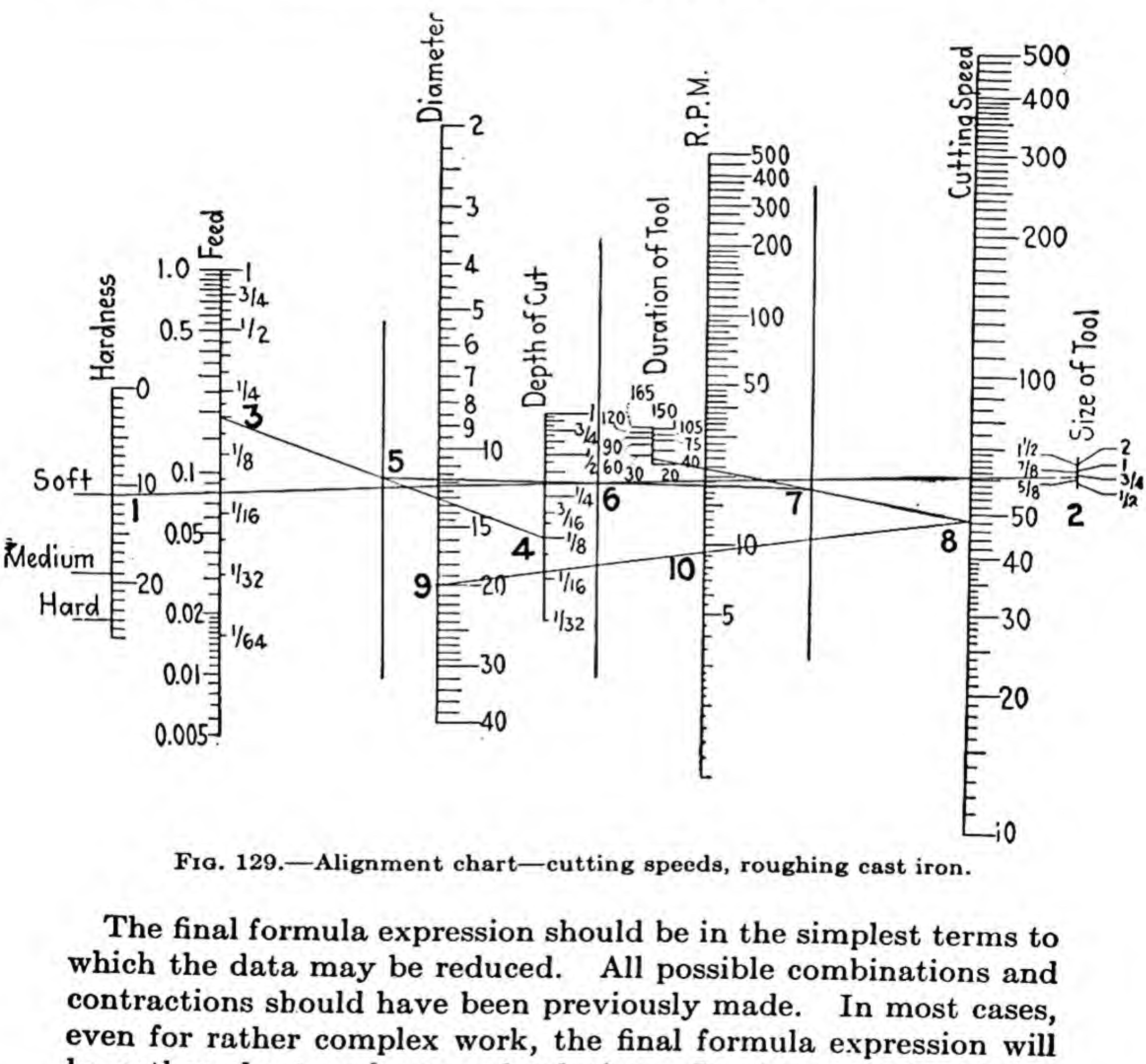


Fig. 129.—Alignment chart—cutting speeds, roughing cast iron.

The final formula expression should be in the simplest terms to which the data may be reduced. All possible combinations and contractions should have been previously made. In most cases, even for rather complex work, the final formula expression will be rather short and easy of solution. In the examples which follow, the surprising amount of condensation which is possible is clearly shown.

CHAPTER XXIX

TESTING AND SELLING THE FORMULA

After the formula has been put into its finished shape, the time-study man must satisfy himself as to its accuracy. Before he can attempt to sell the formula to anyone else, he must have complete confidence in it himself. He should have the confidence which is born of knowledge and ability, and he will then strengthen this confidence by testing the formula thoroughly under the conditions of actual use.

There are three general ways of testing a formula. The most reliable and satisfactory way is to select, from the time studies taken on the work to which the formula is meant to apply, a number of studies on various jobs which will be considered as being representative. Then for these jobs the allowed time is calculated from the formula and checked against the time derived from the studies. These studies are usually available from those taken while collecting data for the formula. The other two ways are by checking formula values against existing values established by time study and by checking formula values against time-study values and overall checks obtained for the purpose. The first method involves less actual work and is used wherever a sufficient number of time studies are available.

Checking against Existing Time Values.—Wherever any time-study work has been done, there are generally some time values established on jobs which were made at one time in fairly large quantities. These values may be conveniently used for checking a newly compiled formula. A form similar to the one shown in Fig. 130 may be ruled to give columns for the job identification, the old time value established by time study, and the new value computed from the formula.

As has been previously pointed out, values set from time study over a period of time by different time-study men are very unlikely to be truly consistent. It is therefore not to be expected that all formula values will check exactly with all time-study values. They should, however, check closely to within a few per cent plus

or minus, and the total of the old and the new values may be expected to be very nearly the same.

When making a check by this method, care should be taken to select jobs which will test the formula from one extreme of its application to the other and not merely to select jobs which are

Drawing number	Item	Old time allowed, hours	New time allowed, hours
616369	4	0.265	0.208
633278	1	0.100	0.100
620074	2	0.260	0.210
623705	1	0.200	0.465
606339	1	0.225	0.199
398543	1	0.140	0.147
604657	5	0.088	0.113
23933	2	0.020	0.020
427389	6	0.007	0.021
376845	1	0.030	0.044
602577	9	0.060	0.060
352437	2	0.025	0.028
402554	3	0.015	0.044
402554	9	0.020	0.025
373259	1	0.014	0.0143
13533	1	0.040	0.050
377898	3	0.083	0.117
723713	1	0.178	0.148
700379	1	0.100	0.130
708267	2	0.040	0.028
419265	3	0.149	0.166
608629	3	0.070	0.059
38691	2	0.200	0.205
341717	1	0.102	0.167
20761	1	0.166	0.156
435215	6	0.034	0.045
334356	20	0.160	0.174
427290	2	0.112	0.114

FIG. 130.—Comparison of old and new time values for sawing asbestos lumber.

all very similar. The check should cover at least 30 or 40 jobs and more if practicable. Greater confidence will be engendered in the minds of those to whom the formula is later to be sold if they are shown a representative list of jobs upon which a check has been made.

Time values which have been established by estimates or overall checks should not be used in testing a formula unless they are considered only for what they are worth. Such values are practically certain to be very inconsistent. If such a value does not check with a formula value, it is quite natural and logical to assume that the old value is incorrect. To be perfectly consistent, any agreement which may be found between old and new values must be attributed mostly to chance. It is better, when only such values are available, to make the test by the third or overall check method.

Checking Where No Accurate Time Values Exist.—In some cases an insufficient number of time values upon which dependance may be placed will be available. It is then necessary for the time-study man to establish time values of his own which will be used solely for the purpose of making the check. He already has on hand the detail time studies from which he constructed the formula. A check of time values worked up from these studies against values set on the same jobs by the formula will tell whether or not the time-study man has compiled his formula correctly from his available data. It will not, however, tell whether or not the formula is truly representative. There is a chance that the jobs on which the formula is based were not strictly representative, and this is one of the things which the test must determine.

The time-study man must, therefore, establish additional time values on jobs which were not used in constructing the formula. It is not essential that these time values which will be used only for checking be established from detail time studies. Detail time studies, of course, will give highly accurate time values, but the accuracy needed for a check does not warrant the amount of time and labor involved. Rather, it is only necessary in most cases for the time-study man to observe one piece being made. He will note the overall time taken, the time for any foreign operations which may have occurred, the skill and effort exhibited by the operator, and the conditions under which he worked.

The overall time less the time taken up by foreign operations multiplied by the leveling factor determined by skill, effort, and conditions, will give the standard time for performing the operation. This time increased by the allowance percentage will give the allowed time which may be used for the purpose of checking the formula. The allowed time thus found will be entirely

accurate enough for the purpose of the check. If any large discrepancy is found between the time established by the overall time check and time computed by formula, a detail time study should be taken to determine which is wrong.

Making Overall Formula Checks.—The making of these overall formula checks may be greatly facilitated by the use of the form shown in Fig. 131. When the check has been made, this form may be filed away with the other data which were used in constructing the formula. The first seven columns are filled in when the check is being taken. The subsequent computations may be performed at leisure.

It is possible, in a comparatively short time, to get overall checks on the 30 or 40 different jobs that are needed for an accurate test, provided that such jobs are being worked at the time. If not, the time-study man will have to watch the floor and take his checks whenever he sees a job being worked on which he has no data. He may, if he wishes, rule up the back of the form so that he can conveniently record thereon the variable characteristics of the particular jobs he is checking. Such a ruling designed to check a formula is shown in Fig. 132. More will be said later about special forms which make easy the collecting of the information necessary for establishing time values by formula.

When the time-study man has collected sufficient data, it is a simple matter to make a comparison. The formula values will be found by substituting properly in the formula. The allowed time may be conveniently computed from the equation:

Allowed time $= NLA$
where $A =$ (per cent allowance $+ 100) \div 100$,
$L =$ leveling factor,
$N =$ net overall time.

Results of the Test.—After the values for making the test have been obtained, the next step is thoroughly to analyze them. If the formula values check closely with the values against which they are being checked, it is necessary only to make certain that at least one of each type of job which will come under the limits of the formula is included in the check. If this is found to be the case, the formula may be considered as definitely correct.

If the formula values do not check with the other time values, it is an indication that further analysis is necessary. If the

Drawing	Item	Overall time	Foreign operations	Skill	Effort	Conditions	Net overall time	Leveling factor	Standard time	Per cent allowance	Allowed time

FIG. 131.—Form used for making an overall formula check.

Pattern number	Number per box	Volume	Strike area	Box area	Base area	Number per plate	Black	Description

FIG. 132.—Form used for collecting variable job characteristics when checking a formula.

formula has been checked against existing time values, it may be felt that the formula is right and that the other values are wrong. Any question of the accuracy of these time values may be settled by making a test by the overall check method. If this test shows the formula to be correct, it may safely be assumed that the existing time values were wrong. Where certain time values check with formula values and others do not, it will probably be found that the formula applies to certain classes of work and not to others. The formula should be revamped so that it will apply to all cases, or its application should be limited and a new formula made to cover the other work. If no agreement at all is shown by the check, the formula must be gone over carefully and checked for errors. In the majority of cases, however, if the formula has been compiled according to the methods given in the preceding chapters, it will be found to check out satisfactorily.

Importance of Selling the Formula.—Once the time-study man has firmly convinced himself of the accuracy of the formula, his next step is to convince everyone else who will come in contact with it that with it time values may be established as well as or better than by time study. This step is particularly important where the idea of the formula is new. It is difficult for anyone not acquainted with the details of formula construction to see how the time-study man expects to establish accurate time values without taking time studies and without, in most cases, even watching the job being done. The impression is likely to be conveyed that time values so given are merely estimates. The workers will often at first complain that the values are too low, thinking that the time-study man has nothing to back up his work. They have little trouble in convincing uninformed foremen that the time-study man is establishing values by guesswork and that his guesses are all too low.

Rather than have this feeling become prevalent, it is better to sell the formula before it is put into actual use. Even in plants where formulas have been used for years, it is well to go over at least briefly every new formula with all who may be interested. Any renascent doubts as to the fairness of formulas will thus be nipped in the bud.

Selling Formulas to the Supervisors.—The first man to convince of the fairness and accuracy of formulas is the plant manager. It will, of course, be necessary to have his backing

before going ahead. He will be interested not so much in any one formula in particular but rather in formula principles and practices in general. A brief outline of the principles given in the foregoing chapters together with a simple formula as an illustration should be enough to convince the manager of the soundness of formula practice. Once convinced, there will be little need of reopening the subject with him.

The superintendent of the department in which the formula is to be used should have the subject of formulas presented to him in the same general way, with perhaps a little more detailed explanation of the formula itself. If the subject is presented to him properly, he will readily see the reasoning behind the formula. He will recognize that certain elemental operations must be performed every time a piece is made and that they will be constant. He will readily see that the deeper a certain sized hole is drilled in cast iron, the longer it will take and that it will require longer to drill a given hole in steel than it will in brass. Such variable relations he will recognize as fast as they are pointed out to him, and in the end he will be convinced that a formula is merely applied common sense. The mathematics involved in formula expression will appear as a mere detail after a thorough explanation of principles, whereas if he were to be presented the formula without the explanation, he would feel that it was all theory and mathematics and of questionable value in everyday work.

The foreman who supervises the work which the formula covers should next be shown the formula. After he understands the principles involved, he will be interested in quantitative details, such as how much time is allowed for performing a certain operation and how another operation is handled. The time-study man will demonstrate, with the list of representative jobs used to test the formula, the accuracy and consistency of the formula. He will call attention to the fact that, as the job characteristics which affect the time vary, the time allowed varies in a proper proportion.

Selling Formulas to the Workers.—It is seldom practicable to give such a complete explanation of formulas to every worker who is to work under them, although the time-study man is always ready to go into it with any who may be interested. Rather it is a case of selling the time values themselves. If the worker is convinced that he can meet or better a number of

time values and that all other values will be set in the same way, he will not question the method by which they are set. The longer he works under such time values, the more he comes to appreciate their accuracy and consistency. The vast fair-minded majority of workers will not question any time values unless a question is justified because of some clerical error in computing one particular time value. Thus it may be seen that formulas, once proved correct, bring about better feeling between time-study men and workers and decrease the number of complaints and arguments both justifiable and unjustifiable.

CHAPTER XXX

THE FORMULA REPORT

After the formula has been compiled and tested, there remains only the writing of the formula report before it may be considered completed. The formula may be used by the time-study man who made it or by others under his personal supervision before the report is written. This is not, however, the best practice. Once the formula has been put in use, there will be so many details arising to claim the attention of the time-study man that he will have little time for a week or more to work on the report. When he has time, he will probably be wanted badly elsewhere, and he will tend to let the report go for a still longer time. When he finally does get to it, the details of the formula are no longer fresh in his mind, and the report suffers accordingly. Therefore, if possible, the report should be written as soon as the actual formula is completed.

What the Report Is.—The formula report tells in full all the details of the construction of the formula, and it also gives a clear account of just how the formula is to be applied. A good formula report should make two things possible. First, it should enable anyone to check back at any future period and see where and how each value was obtained. The element analysis will show the reasoning process followed by the time-study man in dealing with each individual elemental operation. The formula report will show just how these values were combined and built up into the final formula and will also enable one to trace back to the original study from which each value was taken. Second, the formula report will make it possible for anyone who is familiar with formulas in general to apply the particular formula even though he has never seen it before. The importance of the report should now be clearly apparent. In order that the report may do all that it should do, it must be written in a clear manner, and it should overlook no detail connected with the formula. A good report is not easy to write, but any time spent to make it per-

fectly clear will pay for itself time and again. The time-study man who made the formula will not always be available for questioning, and when he is not, the formula report must furnish all the information required.

Now and then some workman gets the idea that he is doing something on the job which has not been considered in the time allowed. If he is right, the formula should be revised to take care of it, but if it has already been taken care of, the formula report should show conclusively that this is the case and also just how much time is allowed on any particular job. As an example, on the operation of winding revolving field coils, it was necessary to replace empty wire reels with full ones, the size of the coil being wound determining the number which could be made from each reel. The time required to change reels complete was found to be 0.1400 hour. Upon checking a number of reels it was found that the average weight was 100 pounds. It was decided to include time for this work with the time for winding the coil. This was done by dividing the time taken to change reels by the average weight of a reel of wire, which gave the time to change reels per pound of wire as $\frac{0.1400}{100}$ or 0.0014 hour. Then to each coil was added the time to change reel per pound of wire times the number of pounds the coil weighed, which would be in the case of a 20-pound coil 20×0.0014, or 0.028 hour. One of the operators who was engaged on this work did not understand how this was taken care of and questioned his foreman. The foreman took the matter up with the time-study man who secured a copy of the formula report which very completely and comprehensively explained how this time was added. The evidence was there and could not be disputed. The operator and foreman were fully satisfied and were sold to the formula method of establishing allowances. If the formula report had not been complete in this respect, it might have been difficult to convince these men and might have aroused their suspicions as to the honesty of purpose.

Report Outline.—The formula report should be written up in standard form both to insure a uniformity of practice throughout the plant and, more important, to minimize the chance of the omission of any pertinent facts. The standard subdivisions which should be used in all reports are as follows:

Formula Number
Date

Part:
Operation:
Work Station:
Allowed Time:
Application:
Analysis:
Procedure:
Time Studies:
Table of Detail Operations:
Synthesis:
Inspection:
Payment:

In addition to these standard subdivisions, any other set of facts which it is desirable to keep apart may be placed in separate subdivision with an appropriate subheading. At the end of the report, space should be left for the signature of the time-study man who made the formula and for the approval signature of his immediate superior.

Formula Number and Date.—Every formula should be assigned a number by the man in charge of time-study work in the department where the formula is to be used. The formulas may be numbered from one on up in the order in which they are compiled. This number will serve to identify the formula definitely and it will also give a convenient filing index.

In large plants, it is well also to identify the formula with the department to which it belongs. Thus Formula *A*-10 No. 3 would identify the formula as being the third which was applied in department *A*-10. Such identification practically eliminates the chance for duplicate formula numbers in different parts of the plant.

The date is, of course, the date upon which the formula is first applied. It is extremely important to have this date recorded, for it enables one to check back and definitely determine just what conditions were at the time the formula was made. If any objection to time values is raised on the grounds of changed conditions, it will thus be easy to determine whether or not the objection is valid.

Part.—Under the subheading of Part should be listed the general classes of parts to which the formula will apply. This may generally be expressed in a few words as "all small alloy

and cast-iron castings," or "slate panels up to size 22 by 48 by 1 inches. Wherever the formula applies to a line of work which is identified by type, style, or other numbers or letters, this nomenclature may be used with a gain in conciseness. "Type *AP* and *AF* autostarters," or "801 switch groups," clearly identifies the parts to which the formula applies.

Operation.—The operation which the formula covers is noted under this subheading. This again may usually be expressed in a word or two as "mill," "assemble panel to cabinet," or "cut off to length." Where the formula is more comprehensive and covers a number of different operations performed by one operator or group of operators, every operation included in the formula should be listed for the sake of clearness.

Work Station.—The work station at which the operation is performed should be designated here. If the work is done on a bench or the floor of the shop without the use of machine equipment, "bench" or "floor" describe the work station sufficiently. Where machines are used, a complete description of each machine covered by the formula should be given. The size, type, maker's name, and other identifying information should be fully listed. If the plant assigns numbers of its own to the machine, these should also be recorded. Such complete descriptions will eliminate much future argument when the time-study department revises its formulas because of new and improved machine equipment. There will be no doubt that the revision is due to a change in equipment and not due to an arbitrary cutting of time values.

Allowed Time.—Under this subheading are given the algebraic formulas for computing first-piece and additional-piece times, together with a key to the symbols used. All tables used in connection with the formula are included here. In short, all the information necessary for computing time values when one is familiar with the principle of the formula is given under Allowed Time. It contains the real meat of the formula report. Some examples of the form in which the allowed-time information should be recorded are given in the formula examples in Chaps. XXXIII to XXXV.

Application.—A clear concise statement of the work to which the formula applies should be given under the subheading of Application. If words are chosen carefully, it is generally possible to state the formula application in a single sentence. The following is an example of the manner in which it should be recorded:

This formula applies to the molding of all alloy castings on Tabor Vibrator Molding Machines, Company Nos. 6208 to 6217 inclusive, as done in the brass foundry at the present time with the present auxiliary equipment, sand, metal, and other conditions being as of May 1, 1939.

It will be seen that the first part of the above application is merely a repetition of what has already been stated under Part, Operation, and Work Station. The second part definitely limits the formula to the conditions which were in effect at the time the formula was compiled. The time-study department goes on record saying that the formula will hold good as long as conditions remain unchanged, and the workers are given this additional assurance that time values will not be reduced to limit earnings. At the same time, the time-study department retains the right to change the formula when conditions change, which is but just. The workmen, of course, know that only the time values which are affected by the changed conditions will be adjusted, and they are rightly certain that a minor change in conditions will not be used as an excuse to revise the whole formula.

If the formula applies only to certain sizes of work within a given class, it should be clearly noted under Application. This will serve to inform whoever may be applying the formula of its particular limits of application.

Analysis.—Under Analysis should be told the complete story of the formula. Any point which may need stressing or amplification should be brought out here and everything which has a bearing on the final formula should be explained.

First, a list of the small tools and equipment other than the actual machine should be given. This will include such things as wrenches, pliers, screwdrivers, clamps, dogs, chucks, center punches, brushes, gages and measuring tools of all kinds, surface plates, jigs, fixtures, and any other equipment which may be required to perform the operation.

Next should come a list of the supply materials required, if any are needed. Under this heading would come tape, cotter pins, nuts and bolts, wood screws, escutcheon pins, cutting oil, waste, solder, and other miscellaneous supply material. Such material is generally used on assembly or partial-assembly operations.

A brief but complete outline of the material-handling situation should be given under Analysis. Whether or not material is

handled by special laborers should be noted in order to justify the way handling time was cared for in the formula. If supply men are added or removed at some later date, the time-study department needs to have something definitely recorded about past material-handling conditions, so that it will be able to justify any change in time values which it may be necessary to make. Under this head should be included a description of material-handling equipment such as jib cranes, lift trucks, and the like.

Then should follow a description of how a job is given to the workers and what they must do in the way of getting drawings, tools, supplies, and information before they can start to work. This paragraph will contain a word about any unusual elemental operations, which have been included in the first-piece time. It will also explain just how the time spent in gaging, checking, and finding dial positions on the first piece is allowed for.

Another paragraph under Analysis should give an account of how finished work is counted and checked and how the worker is allowed time for the work he has done. This will include mention of any unusual features in the work of the payroll clerks.

All allowances which have been added to standard-time values should be carefully explained. The ordinary allowances for personal needs, unavoidable delays, and fatigue should be mentioned quantitatively with little or no elaboration. All special allowances should be explained in detail. The reasons, method of determination, and numerical value should be stated clearly and the items which they are to cover should be so given as to minimize the possibility of ambiguity. This point is very important, for both workers and foremen are quick to point out any necessary elemental operations which they feel have not been covered in the formula. Unless all operations that were included in the special allowances are carefully noted, it is quite possible that the same allowance will be added again at some later date.

Other paragraphs under Analysis may be devoted to any additional points which come up in the particular formula being written up. Any unusual features which may come up in doing the work are here discussed. Wherever a word or two of explanation will serve to clarify the formula expression and make the procedure for applying the formula more easily grasped, it should be given. The willingness of the time-study department

to help and cooperate with the workmen may be reflected in suggestions and remarks on how it will be possible to save time by combining trips to the tool or drawing rooms and other similar ways. Not only will this assist the worker to increase his earnings by planning his work, but it will also help to secure greater production from a given equipment.

The time-study man should not try to complete his writeup of Analysis in one sitting. He should record all the points that he can think of when he starts, but he will very probably find that other points continually occur to him as he is writing the rest of the report. These he should add until he can think of no more. A good plan then is to show the rough report to a fellow time-study man and to ask his opinion of it. The questions that this man will ask will quickly show where the report is lacking in clearness and detail. Points that may seem obvious to the man who has worked with the formula from the start will be questioned, and the writer will thus find where addition or elaboration is necessary.

Procedure.—The manner in which the complete operation is performed should be given in outline form. It will be little more than the names of the elemental operations strung together in the order in which they are performed. Operations which are done only occasionally when necessary on a particular class of work should be so marked. The whole purpose of this subdivision is to give one a concise word picture of what the operator must do to perform the operation completely.

Time Studies.—Under this subheading should be given a list of the time studies which were used to compile the Master Table of Detail Time Studies. Three headings may be made as follows:

Study Number	Date Taken	Taken by

In the first column should be noted the numbers which were assigned to the studies as they were placed on the Master Table as *S*-1, *S*-2, and so on. The date on which the study was taken is recorded in the second column and the initials of the time-study man who took the study in the last. This list of studies will be useful in checking back from the formula to the original studies at any future period. It also gives an idea of who made the studies and when.

Table of Detail Operations.—Here is recorded the information which is contained in the first four columns on the Master Table.

The Table of Detail Operations should be headed up as follows:

Symbol	Operation Description	Allowed Time	Reference

This table gives a complete list of all of the elemental-time values which were used in constructing the formula. It will be valuable for reference when anyone questions how much time was allowed for a certain operation. In the Reference column are shown the numbers of the studies as they appear on the Master Table from which the allowed-time values were selected.

Synthesis.—The Synthesis subdivision, as its name implies, shows how the formula for allowed time was built up from the data given in the Table of Detail Operations. First, it shows what elemental operations were combined to form constants. This is clearly denoted by algebraic expressions. The letters which are used in these expressions correspond to the letters in the Symbol column in the Table of Detail Operations. The expression is given first in purely algebraic form as so many A's plus so many B's and so on; next is shown the substitution of the numerical time values; and finally is given the summation of these values or the constant which will be used in the formula expression. The synthesis of each constant used both in the first piece and in the additional piece expression is thus shown in detail.

Under Synthesis, the derivation of all curves is also given. Each curve is discussed separately in detail, and the relation between time and the variable characteristic is gone into. Any synthesis of the curves themselves is also shown, as are all derivations of algebraic expressions from curves. Any information which will show how tables of computed values were compiled should be included under this head.

Inspection.—The inspection standards that are in vogue at the time the formula was made should be recorded under this heading. Inspection requirements are no more fixed than many other things which affect the amount of work which must be done. If the requirements are made more rigid sometime after the formula has gone into effect, it is only fair to the workman to allow him more time, if more time is required to produce a better job. The time-study man will wish to know what the standards were when the formula was made in order that he may be certain of how much has already been allowed for. If, on the other hand, it is decided that a less carefully made job will be satisfactory or that a smooth surface with no tool marks is not necessary, then the company

will be entitled to the saving thus effected. Here again the former requirements must be known in order that the time-study man may make the adjustment fairly and to the satisfaction of all.

The inspection requirements may be learned from the inspection department. If written inspection standards are available the time-study man is safe in incorporating them under the Inspection subdivision. If not, the time-study man must ascertain the requirements by questioning the inspector. He must be very careful not to take any answers which are given offhand, and he should satisfy himself that the inspector will actually require all that he says he will. The time-study man, of course, investigates the inspection requirements before he takes any time studies, as was explained in the early part of this book.

Payment.—The name of the wage-payment plan under which formula values will be applied should be given in this subdivision. If it is the standard system which is used in the plant as a whole, merely the name need be given. If some special system designed to meet special conditions is to be used, a complete explanation of the workings of the plan should be made.

Special Subdivisions.—Any important features of the formula report which do not properly fall in any of the above standard subdivisions may be handled separately and specially. Where a certain line of work is divided and classified as small, medium, or large, simple, medium, or complex, or according to some other method, a special subdivision defining exactly what is meant by each of these terms is practically essential to the correct application of the formula. Several examples of special subdivisions will be noticed in the examples of formula reports which are to follow.

Signatures.—Every formula report should be signed in ink by the time-study man who made it. It should also bear the signature of the time-study supervisor. The title Time-study Supervisor is used to denote the immediate superior of the time-study man. His actual title will vary with the plant with which he is connected. The typing in the space for signature should be in the following form:

Approved:

Time-study Supervisor	Time-study Department

These signatures should come at the end of the formula report.

Formula Working Sheets.—The routine time-study man who is to apply the formula does not need to refer in his daily work

Formula *P*-2 No. 26.
Nov. 15, 1939.

Part:
Controller shafts.

Operation:
Grind gear, handle, star wheel, and bearing fits.

Machine:
Norton grinder, size 6 by 32 inches (2-inch stone) No. 23793.

Standard Time:
First-piece Time.—$0.163 + T + 3$ (each additional-piece time).
Additional-piece Time.—$0.0175X + 0.0016L_s + 0.0134Y + 0.0087 (L_t - 1) + 0.0021$

where L_s = total length in inches of fits $1\frac{7}{8}$ inches or under.
L_t = Total length in inches of fits over $1\frac{7}{8}$ inches.
T = values from Table I.
X = number of fits $1\frac{7}{8}$ inches or under.
Y = number of fits over $1\frac{7}{8}$ inches.

TABLE I.—TRUE STONE

Number of Fits per Shaft	Decimal Hours
1	0.1068
2	0.1068
3	0.1602
4	0.2136
5	0.2670

Application:
This formula applies to rough and finish grinding of shafts up to and including 6 pounds where length of fit does not exceed 8 inches, as done in Sec. *P*-2 with methods and equipment as at present.

Inspection:
Inspected for size. Inspection requirements are:

Handle, star wheel, and gear fits.	$\begin{cases} +0.0005 \\ -0.0000 \end{cases}$
Bearing fits.	$\begin{cases} -0.0010 \\ +0.0000 \end{cases}$

Payment:
Standard-time job basis.

Approved: A. V. Grear, Time-study Supervisor — Jas. C. Carter, Time-study Department

FIG. 133.—Example of formula working sheet.

to all of the subdivisions included in the formula report once he has become familiar with what is contained therein. He will use chiefly the material contained under Allowed Time although there

are several other items which he should have before him. He is very likely to be using more than one formula, so in order to cut down the bulk of paper and in order to make it more convenient to handle the formulas, formula working sheets should be made which will contain only the information which is needed to carry on the daily work of setting time values. These working sheets should include the formula number and date; part, operation, work station, allowed time, application, inspection, and payment subdivisions; signatures; and all tables, curves and charts.

The formula working sheets may be typed up in the manner shown in Fig. 133 on thin paper, and for the sake of the appearance, within the bounds of a heavy border. From these sheets blueprints may be made which will be the working sheets used by the routine time-study man. By the use of blueprints, the replacement of dirty or torn working sheets becomes a comparatively inexpensive matter. The typewritten formula report may be kept in a clean place, and since it is handled infrequently, will remain legible for a number of years.

The working sheets of all the formulas used by one time-study man may be kept together arranged in numerical order in a clamp cover. From this one book, the time-study man will then be able to set time values on all of the work which he handles. He will always keep his formula reports filed conveniently, so that he may readily check back on any point of formula construction and show definitely how every point was cared for.

CHAPTER XXXI

CLERICAL ROUTINE

When the formula report has been finished, the formula, as far as the time-study man is concerned, is complete. There remains, however, a certain amount of clerical work necessary to put the formula and all the paper work connected with it into the best permanent form for use and reference. If this is not done systematically, part of the data or computations or rough curves will very probably soon become mislaid, and any rechecking or revising of the formula will become increasingly difficult as time goes on. Anyone who has tried to piece together the details of the construction of an old formula from a few scattered time studies and some unidentified computations will readily recognize that time spent in putting such information into shape for reference is time well spent indeed.

Stenographic Work.—The formula report and the formula working sheets should be typewritten in order to have them in neat legible shape. At least three copies of the formula report should be made and more, if more than one routine man is to apply the formula. Only one copy of the working sheets is made, and duplicates are obtained by blueprinting.

Unless the time-study man can do exceptionably good freehand lettering, typewritten scales, titles, and the like on all curve sheets promote neatness and uniformity of appearance. Most tables may be typewritten to advantage except where more compactness than is possible with a typewriter is desired.

Working Data.—All the data which were used in making the formula should be gathered together and kept on hand for reference. This may be done conveniently by placing all such data in a paper envelope about 9 by $11\frac{1}{2}$ inches in size. Such an envelope will be practically dustproof, and it will hold very nicely all the miscellaneous sizes and shapes of paper upon which various pieces of information may have been recorded. For purposes of identification and filing, number, part, operation, and date of the formula should be marked on the upper right-hand

corner of the envelope. Figure 134 shows a form in which this information may be arranged. A rubber stamp may be used to mark this form on the envelope. Where more than one envelope is needed to hold the working data, the total number of envelopes used should be marked on each envelope. One may thus always be sure as to whether or not he has a complete set of data.

FORMULA........................
PART............................
OPERATION.......................
DATE............................

Fig. 134.—Form used for formula identification purposes.

An itemized list of what should be placed in the envelope is as follows:

All time studies.
Master Table of Detail Time Studies.
Element analysis.
All rough curves and computations.
Sketches.
Pencil copy of formula report.
Formula test data.
Extra copies (at least one) of formula report.
Extra blueprinted working sheets.
Miscellaneous data bearing on formula.

Related data should be clipped together and marked. The contents of the envelope will in the majority of cases subdivide itself into the groups given in the above list. If these groups are kept separate and are properly marked, much subsequent hunting will be eliminated.

Central File.—The original typed formula report and the typed formula working sheets should be placed together in a white manila folder. The formula identification form may be stamped on the folder with the rubber stamp previously mentioned. This folder should be kept in a central file in the office of the head of the whole time-study organization. There will be less chance of this information becoming soiled or lost in a file of this sort than there is in the less permanent files out in the shop offices. In addition, all formulas come under the inspec-

tion of one man. Knowing what has been done towards formulating data on a certain class of work in one department, he will be in a position to prevent any duplication of effort in other departments. He will be able to supervise formula work in general and will know whether or not standard practice is being followed. If he comes across a good new idea developed by one time-study man, he will quickly pass it on to all other time-study men.

When new blueprint copies of formula working sheets are needed, it is necessary merely to call the central file and request that they be made. If these sheets were kept by the individual time-study men or even by the time-study supervisors, the chance for certain sheets becoming mislaid or lost is readily apparent.

Establishing Time Values by Formula.—The routine work of establishing time values by formula should be carefully considered, for any work which may be saved will be multiplied by many time values. The routine will vary with the nature of the work and the nature of the formula. It has, in general, five main steps; jobs upon which no time values have been set must be brought to the attention of the time-study man; the time-study man must collect the information necessary for applying the formula; he must compute the time value; he must tell the worker what the time value is to be; and he must make a permanent record of the time value so that he will not have to compute it every time the job comes along.

Ascertaining What Jobs Have No Time Values.—A workman likes to know what the allowed time is before he starts in on a job. Not only that, but he is likely to withold his best efforts until he learns what the time value is, thinking that the time-study man may be influenced by what he does. An explanation of the way time values are set will serve to minimize this feeling, but it exists to quite an extent in a number of cases. Both in order to satisfy the workman and in order to speed up production, it is desirable, if possible, to establish time values before the job is worked. Whether or not this is possible and how it may best be done are dependent upon the nature of the formula and the particular dispatching system used for starting jobs through the shop.

With certain machine formulas, it is necessary to see the job made and to get the actual cutting time taken. This is, however, generally due to the fact that insufficient data on feeds and speeds are available, and comprehensive data will eliminate the necessity

for timing such jobs. Where such formulas are in use, it is obviously impossible to establish a time value before the job is started. In cases like this, the worker notifies the time-study man when he is ready to start the job. The time-study man goes out on the floor and gets his data as soon thereafter as he has a little spare time.

Most formulas permit the establishment of time values either from the drawing or from the piece being worked. Where it is possible to use drawings, the workmen bring them to the time-study man whenever they get them where no definite dispatching system is used. Attached to the drawing is the time slip of the worker. When the time-study man has computed the time value, he notes it on the time slip. The workman gets the drawing and the time slip on his next trip to the office. By getting drawings and time slips ready as soon as he knows that he is to do a certain job, the worker will be able to obtain the time value before he is ready to do the actual work.

When work is given out at a central dispatching station, the time-study man can periodically examine the jobs which are to be made and can easily have the time values set before they are due to be worked.

Collecting Information.—The time-study man must get together certain information before he computes time values from his formulas. Where he can obtain this information from a drawing at his desk, he can look up each variable when he is ready to use it. When, however, he must go out onto the floor or to the dispatching station and examine the job itself, he must record all necessary information in such form that he can use it later at his desk. He will find it very useful to draw up some sort of special form which will enable him to record the information in an understandable manner, to be sure that he has recorded all that he will need, and to place the information in convenient form for substitution in the formula.

An example of such a form is given in Figs. 135 and 136. This form is used with a sensitive drill press formula. It is necessary to go out on the floor to examine the nature of the drill jig when one is used. The other data may be obtained from the drawing of the part, but the form will facilitate recording them and computing the final time value.

Considerable ingenuity may be exercised in devising such forms. If the routine man has the inventiveness and vision necessary for

compiling formulas, he will reflect it by devising such labor-saving forms. Any tendency in this direction will be heartily

Size Material	Jig Vise Table	AVEY DRILL PRESS Operation	Item Sub.	Drawing			
E	No. spindles not tapping			K	No. of blind holes		
F	No. spindles tapping				Constant		
G	No. drills over 5/8" diameter						
A	No. of clamps			R	No. parts turned in vise		
B	No. jigs blown out-turn over			S	No. holes same size minus		
B-1	No. jigs cleaned with brush			T	No. thumb nuts		
C	No. covers opened and closed			U	No. times jig is turned over		
C-1	No. covers put on and taken off				Constant		
H	No. of hexagon nuts				Miscellaneous values		
I	No. times bushing is inserted				How handled		
L	No. locater screws—hand						
L-1	No. locater screws—wrench				First Piece		
M	No. spindles				Each Additional Piece		
P	No. of parts in jig or vise						

Fig. 135.—Face of form used for recording job characteristics to facilitate establishing time values on Avey sensitive-drill press work.

Drill Size	Depth Drilled	Value From Table	No. of Holes	Allowed Time	Tap Size	Depth Tapped	Speed	No. of Holes	Thds. Per In.	Allowed Time
					Countersink					
					Redrill					
					Ream					
									Formula F-1 #12
Note:	If counter-bored, mark CT.								Date	

Fig. 136.—Back of form shown in Fig. 135.

encouraged by the time-study supervisor who is continually on the lookout for men who have the necessary caliber to become time-study experts.

Computing the Time Value.—Computing the time value is theoretically merely a matter of substituting certain quantities in an algebraic expression and determining the result, but here,

Size Medium Material Alloy #6	Jig	AVEY DRILL PRESS Operation Drill, Burr, and Tap			Item 1 Sub. 6	Drawing 721906	
E	No. spindles not tapping	5	.2090	K	No. of blind holes	1	.0192
F	No. spindles tapping	1	.0683		Constant		2928
G	No. drills over 5/8" diameter	—					
A	No. of clamps	—		R	No. parts turned in vise	—	
B	No. jigs blown out-turn over	1	.0014	S	No. holes same size minus 1	14	.0196
B-1	No. jigs cleaned with brush	—		T	No. thumb nuts	3	.0036
C	No. covers opened and closed	1	.0006	U	No. times jig is turned over	5	.0060
C-1	No. covers put on and taken off	—			Constant	—	
H	No. of hexagon nuts	—			Miscellaneous values	—	
I	No. times bushing is inserted	3	.0030		How handled	—	
L	No. locater screws—hand	2	.0062				
L-1	No. locater screws—wrench	—			First Piece		.679
M	No. spindles	6	.0108		Each Additional Piece		.090
P	No. of parts in jig or vise	1	.0040				

FIG. 137.—Face of form shown in Fig. 135 filled in.

Drill Size	Depth Drilled	Value From Table	No. of Holes	Allowed Time	Tap Size	Depth Tapped	Speed	No. of Holes	Thds. Per In.	Allowed Time
13/32	5/8	.0014	4	.0056	24	3/8	950	4	24	.0028
17/32	3/4	.0018	4	.0078						
25/64	1	.0021	3	.0063						
242	5/8	.0011	4	.0044						
					Countersink					
					Redrill					
					Ream					
					12 Holes Burred .0084					
					Formula F-1 #12					
Note: If counter-bored, mark CT.					Date 6-5-26					

FIG. 138.—Back of form shown in Fig. 135 filled in.

again, much ingenuity may be shown. The man who is applying the formula will find that certain conditions occur frequently, and he will be able to save himself time by making up tables and

lists of figures which will cover these conditions. Time-saving devices that the man who compiled the formula would be unlikely to see should be readily apparent to the man who works daily at applying the formula.

The computation of sensitive drill press time values is made easy by use of the form mentioned above. When the variables have been noted, it is necessary only to multiply the proper values by the number of occurrences, record the products, and add them up. The way the form looks after the value has been computed is shown in Figs. 137 and 138. From this one example, the amount of time that may be saved in the computing of time values by making special forms should readily be apparent. The formula must, of course, be sufficiently active so that the time saved will offset the cost of the forms.

Informing the Worker of the Allowed Time.—The manner in which the worker learns the allowed time will depend on particular conditions. Where he has left a time slip attached to the drawing on the desk of the time-study man, he will find the allowed time thereon recorded when he again gets it. If the time-study man has figured time values on jobs which are still in the dispatching station, he will note the allowed time on some convenient space on the paper work that goes with the job. When it has been necessary to see the job actually worked, the time-study man should make a trip out to the worker and tell him the allowed time as soon as he has it computed.

In any case, the manner of telling is not so important as the fact that the worker should be told. If there is any complaint about a time value, it is better to have it while the job is still being worked. Then, in extreme cases, it is possible to take a detail time study to prove whether or not the value is correct. Otherwise, the best that the time-study man can do is to promise to study the job the next time it comes along, which is satisfactory neither to him nor to the worker.

Permanently Recording Allowed Time.—The allowed time, once established, should be permanently recorded. The routine by which this is done has already been discussed in Chap. IV.

CHAPTER XXXII

FORMULA-REVISION PROCEDURE

There should be a fixed procedure for revising a formula as well as for making the original, for it is just as desirable that the revised product be in standard form as any other formula. The procedure for revising a formula parallels closely that for compilation, although a revision is generally a much simpler task.

Reasons for Revision.—Formulas must be revised because conditions in modern industry do not remain the same year after year, but change with more or less rapidity. Any change which will affect the time for doing the formulated operation is cause enough for formula revision. Before any change is permanently put into effect, it should be certain that it is for the best and not just a remedy for a temporary condition. The revision of a formula and all established time values involves no little expense and should not be made unless there is something to be gained.

Some changes which will necessitate the revision of a formula are the installation of better machine equipment, a radical development in jigs, fixtures, or special hand tools, the introduction of improved cutting tools which will work under heavier speeds and feeds, a change in material-handling conditions, a better method for performing the operation or a change in inspection requirements. It is rather obvious that changes of the above nature will cause a change in the time required to do the work. In fairness to the company when the time is lowered and to the workmen when the time is raised, the formula must be changed.

Collecting Data.—Before the change is made, the time-study man should become familiar with the details of the old formula. He should study in particular the element analysis to learn how each elemental operation is performed. Then when the change is made, he will be in a position to see just what elemental operations are affected. Knowing this, he will make time studies for the purpose of determining the new time on the changed elements.

All elements but those affected may be combined in these studies into as few long operations as is convenient in order to save labor in taking and working up the data. Enough studies should be taken to fix definitely the new time allowed on the changed elements.

Working Up Data.—The general method of working up the data is exactly the same as that used in compiling an original formula. Elements are classified as constant or variable and the time allowed determined accordingly.

Outline of Revised Formula Report.—When the revised formula expression has been completed, it is necessary to revise also the formula report. The report should show the reasons for and the nature of any changes that have been made. The outline of the subdivisions of the revised report is as follows:

Formula Number
Revision Number
Date Revised

Part:
Operation:
Old Work Station:
New Work Station:
Old Allowed Time:
New Allowed Time:
Old Application:
New Application:
Reasons for Revision:
Analysis:
Procedure:
Time Studies:
Additional Time Studies:
Old Table of Detail Operations:
Table of Changed Detail Operations:
Synthesis:
Inspection:
Payment:
Signatures:

The subdivisions which have the same headings as those in the original report remain unchanged. The changed paragraphs will be discussed separately in detail.

Revision Number.—The number of the revision should appear directly under the formula number. This will aid in identifying the report. The date upon which the revised formula is to be first applied is the only date that need be given.

Old Work Station—New Work Station.—The distinction between the old and the new work stations need only be made if the work station has been changed. If it has not, this subdivision should be headed Work Station and the description given should be identical with that of the original report.

A change in work station means, in the majority of cases, a change in machine equipment. Occasionally a bench or special floor fixtures may be devised to replace standard equipment. Such a change would be a change in work station, but they are not often encountered. Under Old Work Station should be given the description which appeared in the original report under Work Station. The description of the new equipment will be given under New Work Station.

Old Allowed Time—New Allowed Time.—These headings are self-explanatory. The old allowed time is given largely for reference purposes. Occasionally it may be necessary to check a time value to see whether it is a new or an old formula value or whether it was set by time study. Substitution in the two formula expressions will settle the doubt. The new allowed time data are those, of course, which are used in establishing time values.

Old Application—New Application.—The headings again explain themselves. The new application shows the conditions under which the revised formula is applicable. The old application is inserted as a reference and to add clearness to the report as a whole.

Reasons for Revision.—Under this heading should be given a clear analysis of the difference between old and new conditions. The way in which changes affect parts of the allowed time should be explained in detail. Any former elemental operations which are rendered unnecessary by the change should be listed. This subdivision is to the revision what Analysis is to the original report. The same items should be taken up and discussed in so far as they have been changed. A clear and logical outline of the line of reasoning followed in making the revision should be set forth, both as a matter of record and as an aid to the making of further revisions.

Additional Time Studies.—The time studies which were taken for the purpose of the revision should be listed in the same manner as the original time studies. A new Master Table of Detail Time Studies was probably compiled, and in order to avoid con-

fusion, its study numbers should be given a subscript as $S\text{-}1_R$, $S\text{-}2_R$, and so on.

Table of Changed Detail Operations.—The work involved in giving an old and a new Table of Detail Operations is considerable, and it is not necessary to do this unless the majority of elemental operations have been changed. In most revisions, only a small percentage are changed, and in such cases, it is more convenient to insert simply a Table of Changed Detail Operations after the old table.

The Table of Changed Detail Operations may, in order to insure clearness, be divided into three parts; Canceled, Revised, and Added Detail Operations. Such a division makes apparent at a glance just what was done in changing the values used in making up the formula expression.

Other Points.—Under Synthesis, any changes which may have been made in the expressions from which constants are obtained should be shown. The best way to show this will vary with the nature of the expression. The explanation of the change need not be elaborate, but it should be clear and easy to follow. Any changes which have been made in curves should also be gone into fully.

If a change in inspection requirements has been the cause of the formula revision, the old and the new standards should be set forth under separate heads. If not, Inspection will be the same as in the original formula report.

If a number of individual operators whose performance was checked and earnings calculated on a day basis were organized into a group, then the group's performance would be checked and earnings calculated on a pay period basis. The change in wage-payment plan would be shown under the Payment subheading.

The revised formula report is signed in the same manner as the original. New working sheets will be made up which will show all changes which come under the work station, allowed time, application, inspection, and payment headings. The subdivision on Reasons for Revision should be included on the working sheets.

Clerical Routine.—Typewritten copies of the revised formula report and of the new working sheets should be made out as before. All blueprinted copies of the old working sheets and all but the original copies, pencil and typewritten, of the original formula report should be destroyed.

All data used in revising the formula should be sorted out, clipped together, and marked in the same way that the original data were handled. They should be filed away in the envelope with the original data.

Nothing should be destroyed from the white folder. The original of the typewritten copy of the revised report and the original typewritten revised working sheets should be filed with the old. The revision number should be placed on the outside of both the envelope and the white folder.

CHAPTER XXXIII

FORMULA FOR PANEL MOUNTING

It is the purpose of these next few chapters to give examples of formulas which have been compiled and successfully applied in order to demonstrate clearly the wide range of work which may be covered. In addition, the construction of the formula on panel mounting given in this chapter will be gone into step by step in order to illustrate by an actual example the points brought out in previous chapters.

The formula on mounting panels in enclosing cabinets was selected for two reasons: first, because it covers a simple operation, and hence does not involve a lengthy discussion of the nature of the work and, second, because it illustrates some of the things that a time-study man should not do, as well as those that he should do.

General Analysis and Survey.—The general analysis of the operation of mounting panels in enclosing cabinets showed, among other things, that panels were mounted in several different ways. They were mounted in some cases on mounting studs, and in others they were bolted to mounting brackets within the enclosing cabinet. The holes in the mounting brackets were laid out for drilling, using the panel to be mounted for a template. Still another type of panel was mounted on the outside of a screen-sided box, and the box itself was assembled by the panel mounters.

A further analysis of the work performed showed that there were only two panels of a special type which were mounted on screen-sided boxes. Hence, it was obviously easier to cover this class of work by time study. The rest of the panels were mounted in enclosing cabinets, and hence it was necessary to get representative studies on jobs taking mounting studs, on the laying out for drilling of mounting brackets, and on the mounting of jobs taking mounting brackets.

A general survey of conditions showed them to be good. Sufficient attention had been given to supplying the proper hand tools and miscellaneous materials, such as bolts, rivets, and the like.

The workers had plenty of room to move about, but cabinets and panels were stored fairly close to them.

Collecting and Tabulating Data.—Three jobs using mounting studs and four jobs using mounting brackets were studied both for layout of the mounting brackets and the actual mounting. The jobs covered a wide range of size, but had it not been that nearly all variable operations were unaffected by whether mounting studs or mounting brackets were used, the number of studies taken would have been insufficient. As it was, the number available was just about the minimum for satisfactory results.

When it came to posting the collected data on the Master Table, it was found that a cardinal point had been neglected. The elemental operations had not been subdivided similarly in all studies. The data covered two Master Tables, and there were few elements for which more than two time values occurred. The work covered by the studies was bench work, and in many cases, it was impossible to split up operations in a definite way because the operator himself varied his method of performance. For example, take the case of inserting four bolts into tapped holes. The first time that the operation was performed, it might be divided into "put in one bolt with fingers" and "tighten one bolt with wrench." The next time this operation occurred in another study, the operator might insert one bolt, tighten only partially with a wrench, repeat this three more times, and then go over all four bolts with the wrench to secure them more tightly. Of course, while there is practically no difference in the overall time for inserting each bolt, it is impossible to make the subdivisions of the first case in the second.

The time-study man should have decided how he wanted each operation performed and then should have instructed the operators accordingly. He would have then been able to divide up the operation into its elements uniformly throughout his time studies. In the particular case under consideration, this was not done, and as there were many reasons for completing the formula as quickly as possible, it was necessary to work with the data at hand.

In order to get the data into good shape, it was necessary to make a number of computations. These were all included in the element analysis so that it is possible to check back and determine how any computed value was derived. Thus the element analy-

sis is somewhat more elaborate for this particular formula than it would be had the data been collected properly. It does do, however, what a good element analysis should do; that is, it shows every step made by the time-study man in arriving at the final values to be used in the formula. The element analysis will here be set forth in detail:

ELEMENT ANALYSIS

		Reference
Mounting Studs:		
Data:		
Place 3 mounting studs in box	0.0123	S-1
Screw on 1 nut with fingers	0.0075	S-1
Tighten 3 mounting studs with screw driver	0.0104	S-1
Place 4 mounting studs and nuts loosely	0.0466	S-3
Place 4 mounting studs and nuts loosely	0.0599	S-5
Tighten 4 studs with screw driver	0.0087	S-3
Tighten 4 studs with screw driver	0.0160	S-5
(1) Place 3 mounting studs in box and put nuts on loosely = 0.0123 + 0.0225 =	0.0348	
(2) Place 4 mounting studs in box and put nuts on loosely	0.0466	
(3) Place 4 mounting studs in box and put nuts on loosely	0.0599	

Assume a straight-line relation as to time per bolt in (1).

$$\frac{0.0348}{X} = \frac{3}{4}. \quad X = 0.0464 = \text{time for 4 bolts}$$

Tighten 3 mounting studs with screwdriver	0.0104
Tighten 4 mounting studs with screwdriver	0.0087
Tighten 4 mounting studs with screwdriver	0.0160

Assume same relation for tightening in (1).

$$\frac{0.0104}{X} = \frac{3}{4}. \quad X = 0.0139 = \text{time for tightening 4 bolts.}$$

Overall time for putting in 4 mounting studs complete:

(1) $0.0464 + 0.0139 = 0.0603$

(2) $0.0466 + 0.0087 = 0.0553$

(3) $0.0599 + 0.0160 = 0.0759$

Time per mounting stud:

(1) $\frac{0.0603}{4} = 0.0150$

(2) $\frac{0.0553}{4} = 0.0135$

(3) $\frac{0.0759}{4} = 0.0189$

On Curve 1, these values are plotted against panel area. The resultant curve is a straight line. The data available do not justify stating that this is an ironclad fact, but since these are all the data available, it must be assumed that they are correct.

From Curve:

Eq. (1). Time for putting in one mounting stud complete = $0.0119 + 0.000028P$, where P = panel area in square inches.

Name Plates:

Data:

		Reference
Lay out 2 holes for name plate	0.0072	S-1
Drill 1 hole in cover	0.0035	S-5
Lay on name plate and rivets	0.0038	S-1
Lay on name plate and rivets	0.0040	S-3
Lay on name plate and rivets	0.0086	S-5
Lay on name plate and rivets	0.0074	S-6
Lay on name plate and rivets	0.0080	S-7
Lay on name plate and rivets	0.0113	S-12
Rivet 2 rivets	0.0056	S-1
Center punch 2 holes	0.0070	S-5
Lay out position of name plate	0.0113	S-2
Mark position 4 holes	0.0068	S-5
Center punch 4 holes	0.0092	S-5
Place on name plate and rivets and cut off 2 rivets	0.0075	S-2
Cut off 2 rivets	0.0029	S-6
Mark position 2 holes	0.0044	S-5
Get name plate and rivets	0.0041	S-7
Get name plate and rivets	0.0071	S-10
Measure for 2 name plates and mark holes	0.0334	S-10
Center punch 8 holes and chalk around	0.0231	S-10
Get 3 name plates and measure position	0.0043	S-11
Mark position 8 holes	0.0131	S-11
Get 3 name plates, measure position, and mark 8 holes	0.0130	S-12
Center punch 8 holes	0.0116	S-10

The procedure in putting on a name plate is as follows:

Lay out position of name plate
Scribe N holes
Center punch N holes
Drill N holes
Lay on name plate and rivets
Cut off 2 rivets $\times \frac{N}{2}$
Rivet 2 rivets $\times \frac{N}{2}$ where N = number of holes in name plate.

Lay out position of name plate.
From S-2 = 0.0113:

(1) Measure for 2 name plates and scribe 8 holes........ 0.0334 S-10
(2) Scribe 8 holes........ 0.0131 S-11
(1) − (2) = 0.0334 − 0.0131 = 0.0203 = measure for 2 name plates.

$$\frac{0.0203}{2} = 0.0102 = \text{measure for 1 name plate.}$$

(1) Time allowed for layout........ 0.0113

Scribe N holes
Mark position 4 holes—0.0068
Mark position 2 holes—0.0044
Mark position 8 holes—0.0131
Plotting this, the Y intercept = time to get ready to mark holes = 0.0013

From curve $\frac{\text{ordinate} - 0.0013}{\text{abscissa}} = 0.0015$

(2) Time to scribe N holes $= 0.0013 + 0.0015 \times N$
where N = number of holes.

Center punch N holes
Center punch 2 holes = 0.0070
Center punch 4 holes = 0.0092
Center punch 8 holes = 0.0116
Plotting this, the curve is drawn at a fair average value taking the data as a whole. Y intercept = 0.0060. From curve $\frac{\text{ordinate} - 0.0060}{\text{abscissa}} =$ 0.00075

(3) Time to center punch N holes $= 0.0060 + 0.0075 \times N$
where N = number of holes.

Drill N holes
Drill 1 hole in cover = 0.0031
(4) Drill N holes in cover $= 0.0031 \times N$
Lay on name plate and rivets:

From time-study data, Curve 4 is plotted. Neither the length of the operation nor the accuracy of the data warrants including such a curve in the final formula. Therefore, the approximate broken-line curves are used. The formula to be used up to panel area $= P = 375$ square inches

(5) Time to lay on name plate and rivets

$$= 0.0032\frac{N}{2} + 0.000018 \times P \times \frac{N}{2}$$
$$= 0.0016N + 0.000009 \times P \times N$$

where N = number of rivets. By actual observation the time required to insert 2 rivets differed negligibly from the time required to lay on name plate and insert 2 rivets.

(5) Above panel area $= P = 375$ square inches. Time allowed $= 0.0100N$

Cut off rivets = cut off 2 rivets $\times \frac{N}{2}$

(6) $$= 0.0029 \times \frac{N}{2} = 0.00145N$$

Rivet rivets = rivet 2 rivets $\times \frac{N}{2}$

(7) $$= 0.0056 \times \frac{N}{2} = 0.0028N$$

Time allowed per name plate = (1) + (2) + (3) + (4) + (5) + (6) + (7).

(1) = 0.0113
(2) = $0.0013 + 0.0015N$
(3) = $0.0060 + 0.00075N$
(4) = $0.0031N$

$(6) = \quad 0.00145N$
$(7) = \quad 0.0028N$
$(5) = \quad 0.0016N + 0.000009PN$
or $\quad 0.0100N$

*Eq. (2) $= 0.0186N_1 + 0.0112N + 0.000009PN$ **for panels up to 375** square inches.

*Eq. (3) $= 0.0186N_1 + 0.0196N$ for panels above 375 square inches.

Where N = Number of holes in name plates.
N_1 = Number of name plates.
P = Panel area in square inches.

Eq. (4). Time allowed for laying out holes per name plate = (1) + (2) + (3) $= 0.0186N_1 + 0.00225N$.

Then in operation 2, "assemble panel to box," where name-plate holes are already drilled, apply the following equations:

Time allowed to put on name plates after holes are drilled = (4) + (5) + (6) + (7).

Eq. (5) $= 0.00585N + 0.000009PN$ for panels up to 375 square inches.

Eq. (6) $= 0.01425N$ for panels above 375 square inches.

Prepare Electric Hand Drill:

0.0121 hour to be allowed per box whenever electric hand drill is used. This is allowed because with two men using the same drill there is some delay in getting electric drill and putting in the proper-sized drill.

Rubber Washers:

Place rubber washer on stud

(1) Place 3 rubber washers on studs.................... 0.0120 *S*-1
(2) Place 4 rubber washers on studs.................... 0.0103 *S*-3

(1) was selected from only one study while (2) was selected from several. Thus (2) may be considered the more accurate.

Using this value,

$$\text{Time allowed per rubber washer} = \frac{0.0103}{4} = 0.0026.$$

Place Panel in Box:

The data do not show any definite variation of time with panel size, as might be expected. Therefore, an average value is selected and the number of men required to lift the panel taken into account.

Eq. (7). Time allowed per panel $= 0.0095 \times M$................ *S*-3

where M = number of men.

Bolt Panel to Mounting Stud:

Data:

Place 6 washers.................................. 0.0101 *S*-1
Put on 3 nuts with fingers........................ 0.0104 *S*-1
Tighten 3 nuts with wrench........................ 0.0125 *S*-1
Put on 8 washers.................................. 0.0138 *S*-3
Put on 1 nut with fingers......................... 0.0025 *S*-5
Tighten 4 nuts.................................... 0.0112 *S*-3

* These equations apply only when name-plate holes have not been previously laid out and drilled. When operation 1 is "lay out box for drilling," apply Eq. (4).

(1) Place on 1 washer $= \frac{0.0101}{6} = 0.00169$ or $\frac{0.0138}{8} =$

0.00172, say.................................... 0.0017

(2) Put on 1 nut with fingers.......................... 0.0255

(3) Tighten 1 nut $\frac{0.0112}{4} = 0.0038$.................... 0.0038

Time allowed to bolt panel to mounting stud $= 0.0017 + 0.0025 + 0.0038 = 0.0080$ per bolt.

Cover Lock:

Data.

Lay out cover lock position	0.0107	*S*-1
Put in 2 rivets and prepare for riveting	0.0057	*S*-1
Place on cover lock	0.0113	*S*-1
Rivet 2 heavy rivets	0.0125	*S*-3
Adjust and remove box	0.0196	*S*-2
Time to remove box (from below)	0.0049	*S*-7
Time to adjust cover lock $= 0.0196 - 0.0049 =$	0.0147	

Time to put on cover lock complete =

$$0.0107 + 0.0057 + 0.0113 + 0.0126 + 0.0147 = 0.0550$$

Chalk Mark Holes:

Data:

Chalk mark 4 holes for filing	0.0120	*S*-2
Mark around 6 punch points	0.0065	*S*-8
Chalk 6 lugs	0.0099	*S*-9
Chalk 7 lugs	0.0204	*S*-10
Center punch 8 holes and chalk around	0.0181	*S*-11
Chalk around 8 holes $= 0.0181 -$ * 0.0116 =	0.0065	
Chalk 4 mounting brackets	0.0116	*S*-11

There seems to be very little agreement here. In general it takes less time to circle a punch point than to chalk an area or mark a hole for filing. By selection:

Time allowed to mark around 1 punch point $= 0.0008$ per point.

Time allowed for all other chalking $= 0.0116$ overall.

Remove Panel from Box:

By selection from data.

Eq. (8). Time allowed to remove panel from box $= 0.0035M$..... *S*-2

where M = number of men required.

File Ream Holes in Panel:

By selection from data.

Time allowed to file ream hole in panel $= 0.0144$ per hole......... *S*-4

NOTE: This is to be allowed only when holes in box are not laid out using panel to be assembled as template.

Template:

Where template is used for laying out holes in cover, the time allowed will be no different from the time otherwise allowed.

* 0.0116 = time to center punch 8 holes.

Bolts (without Nuts) Screwing into Tapped Holes:

Data:

(1)	Put in 4 bolts by hand	0.0440	*S*-12
(2)	Tighten 4 bolts with wrench	0.0224	*S*-2
(3)	Put in 1 bolt with fingers	0.0052	*S*-6
(4)	Tighten 2 bolts with screwdriver	0.0045	*S*-4
(5)	Tighten 1 bolt with wrench	0.0056	*S*-4
(6)	Put in 1 bolt with fingers and tighten	0.0068	*S*-4
(7)	Tighten 1 side bolt with pliers	0.0056	*S*-4
*(8)	Tighten 1 bolt with screwdriver	0.0038	*S*-6

$$\left.\begin{array}{ll} (1) & \frac{0.0440}{4} = 0.0110 \text{ per bolt} \\ (3) & \qquad 0.0052 \text{ per bolt} \end{array}\right\} \text{fingers}$$

$$\left.\begin{array}{ll} (2) & \frac{0.0224}{4} = 0.0056 \text{ per bolt} \\ (5) & \qquad 0.0056 \text{ per bolt} \\ (7) & \qquad 0.0056 \text{ per bolt} \end{array}\right\} \text{wrench}$$

$$\left.\begin{array}{ll} (4) & \frac{0.0045}{2} = 0.0023 \text{ per bolt} \\ (8) & \qquad 0.0038 \text{ per bolt} \end{array}\right\} \text{screwdriver}$$

Time allowed to put in 1 bolt with wrench = (3) + (2) = 0.0108 per bolt.

Time allowed to put in 1 bolt with screwdriver = (3) + (8) = 0.0090 per bolt.

Get Box:

Handling time should vary with size of box but as boxes are located in different parts of stock pile, it is impossible to do other than try to make a fair selection from data.

Time allowed to get box to bench = 0.0075 . . . . *S*-3

Get Panel:

These are more uniformly placed. Plotting handling time *versus* panel area gives Curve 5. The average curve at these points is a straight line.

Eq. (9). Time allowed to get panel to box = $0.0053 + 0.000031P$

where P = panel area in square inches

Cut Off Brass Bolts:

By computation and selection the value 0.0101 per 7 bolts was obtained from *S*-3. Time per bolt $= \frac{0.0101}{7} = 0.0015$ per bolt. *S*-5 gives 0.0051 per 3 bolts, or $\frac{0.0051}{3} = 0.0017$ per bolt.

Time allowed to cut off brass bolts = 0.0015 per bolt.

Fit Panel into Position:

The smaller the panel, the easier it is to fit in place. For convenience, draw an average straight-line curve through the scattered data points.

* This value will also be used in case of the Cline Controller where it is necessary to tighten the screws holding on the side plates and screens with a screwdriver.

Eq. (10). Time allowed to fit 1 panel = $0.000035P - 0.0020$,

where P = panel area in square inches.

This term should be disregarded for panels below 58 square inches in area, as no fitting is necessary in the small sizes.

Tying on Tags:

Tie on instruction envelope	0.0073	*S*-5
Remove tag	0.0053	*S*-10
Replace tag	0.0204	*S*-10
Time allowed for all tying operations	0.0073*	

Remove Box:

Again there is no definite tendency for time to vary with size. Then selection gives:

Time allowed to remove box = 0.0049 per box.......... *S*-7

Put in One Bolt Complete (Bolt with Nuts and Washers):

Put in 6 bolts and tighten	0.0791	*S*-7

Time allowed to put in 1 bolt complete = $\frac{0.0791}{6}$ = 0.0132 per bolt.

Scribe Mounting Bolt Hole for Drilling:

Data:

(1) Mark out 6 holes	0.0077	*S*-8
(2) Mark out 6 holes (2 men)	0.0089	*S*-9
(3) Mark out 7 holes (2 men)	0.0099	*S*-10
(4) Mark out 4 holes	0.0103	*S*-11
(5) Mark out 1 hole	0.0047	*S*-11

(1) $\frac{0.0077}{6} = 0.0013$

(2) $\frac{0.0089 \times 2}{6} = 0.0030$

(3) $\frac{0.0099 \times 2}{7} = 0.0028$

(4) $\frac{0.0103}{4} = 0.0026$

(5) $\frac{0.0047}{1} = 0.0047$

Time allowed to lay out hole = 0.0028 per hole........... *S*-10

Center Punch Mounting Bolt Holes for Drilling:

Data:

Center punch 6 holes (0.0015 per hole)	0.0090	*S*-8
Center punch 1 hole	0.0039	*S*-10
Center punch 1 hole	0.0061	*S*-11

These values vary widely. Use selection:

Time allowed to center punch 1 hole = 0.0039 per hole.

* Tags come only on Type *F* or the *AC* apparatus since this is tested before assembling to box. The type *C* being tested after assembling has no tag. Since boxes are used for both Type *F* and *C*, allow $\frac{0.0073}{2}$, or 0.0036 on every box for tying.

Remove Panel:

Remove panel to stock pile	0.0078	*S*-10
Remove panel to stock pile	0.0056	*S*-9
Remove panel to stock pile	0.0086	*S*-10
Time allowed to remove panel	0.0078	

Put in One Stud Complete:

Allow same as put in 1 bolt complete	0.0132 per stud

As a result of the combinations made in the element analysis, it is possible to boil the values on two original sheets of master tables down into the few values contained on the condensed master table shown in Fig 139. A good explanation of all constants and variables was given under Element Analysis, together with the reasoning followed in determining their magnitude so that it need not be dwelt on further here.

The next step is to derive the final formula expression and to write the formula report. As has been stated, the operations involved in mounting panels in enclosing cabinets divide naturally into three distinct classes. The formula expression for this work may be handled in several different ways, but for this particular case, it seemed best to make three subformulas and to refer to them in one master formula which explains all the general details of the work. Thus when establishing time values on one class of work, one will not be confused by values applying to the other classes.

The master formula report gives all of the general aspects of the work and the method of compiling the formula. The subformulas give in detail the formula expression, synthesis, and such details as pertain especially to the class of work which they cover. The formula report is self-explanatory and needs no elaboration. A study of the synthesis given under the subformulas will show just what values were combined to make the constants shown in the formula expression.

Formula F-13 No. 7.
May 1, 1926.

Part:

Panel enclosing cabinets or boxes.

Operation:

Lay out box for drilling and assemble panel to box.

Work Station:

Bench.

MASTER TABLE OF DETAIL TIME STUDIES

Methods Engineering Council

SHEET NO. 1
OF 1 SHEETS

FORMULA F-13 #7
DATE MAY 1, 1926

PART ENCLOSING CABINETS
OPERATION LAYOUT PANEL FOR DRILLINGS / ASSEMBLE PANEL TO BOX
PERFORMED ON BENCH

COMPILED BY J. A. Smith

JOB CHARACTERISTICS	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	S-16	S-17	S-18	S-19	S-20
STUDY	#1 4-4-24	#2 4-4-24	#4 4-4-24	#1 4-5-24	#2 4-5-24	#3 4-5-24	#3 4-4-24	#2 4-7-24	#1 4-9-24	#1 4-8-24	#3 4-4-24	#1 4-11-24								
OPERATOR	HILER	HILER	HILER	GOTTHERET	GOTTHERET	HILER	HILER	HILER	HILER GOTTHERET	HILER GOTTHERET	HILER	HILER MARIAN								
SKILL	GOOD	GOOD	GOOD	GOOD	AVERAGE	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD								
EFFORT	EXCELLENT	EXCELLENT	EXCELLENT	AVERAGE	AVERAGE	GOOD	EXCELLENT	GOOD	GOOD	GOOD	EXCELLENT	GOOD								
ASSEMBLE	✓	✓	✓	✓	✓	✓	✓					✓								
LAYOUT								✓	✓	✓	✓									
PANEL AREA	50	168	108	778	280	1225	296	298	575	910	127.6	1030								
DRAWING No.	810449	315866	435819	433517	415417	371827	371902	371902	401347	607278	371827	617930								
HOW MOUNTED	MOUNTING STUD	MOUNTING BRACKETS	MOUNTING STUD	CLINE	MOUNTING STUD	MOUNTING BRACKETS	MOUNTING BRACKETS					MOUNTING BRACKETS								

	OPERATION DESCRIPTION		REFERENCE		S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	S-16	S-17	S-18	S-19	S-20
A	PUT IN ONE MOUNTING STUD COMPLETE	EQ. #1		V	.0150		.0135		.0198							.1048								
B	PUT ON ONE NAME PLATE COMPLETE	EQ #2 or #3		V	.0316	.0478	.0351		.0419							.0048								
C	PREPARE ELECTRIC HAND DRILL	.0121	S-1	C	.0121	.0127	.0107		.0166															
D	PLACE ONE RUBBER WASHER ON STUD	.0076	S-3	M	.0040		.0026																	
E	PLACE PANEL IN BOX	EQ #7		V	.0170	.0121	.0095	.0086	.0060	.0081	.0077		.0014	.0148	.0095	.0043								
F	BOLT PANEL TO MOUNTING STUD, PER STUD	.0080	COMP. E. A.	C	.0110		.0065		.0065															
G	PUT ON ONE COVER LOCK	.0550	COMP. E. A.	C	.0519		.0534																	
H	REMOVE BOX	.0049	S-7	C			.0044		.0045	.0061	.0049	.0084	.0035	.0105	.0042									
I	CHALK AREAS OR MARK HOLES FOR FILING	.0116	S-11	C		.0120						.0065	.0099	.0204	.0116									
J	PUT IN ONE BOLT WITH WRENCH	.0108	S-2 AND 4	C		.0108		.0108								.0110								
K	REMOVE PANEL FROM BOX	EQ #8		V		.0035		.0029			.0044				.0058									
L	GET BOX	.0075	S-3	C			.0075	.0062	.0039	.0091	.0065	.0121	.0071	.0122	.0116									
M	GET PANEL FROM OR REMOVE PANEL TO STOCK PILE	EQ #9		V			.0081		.0123	.0110	.0171	.0036	.0078	.0107		.0122								
N	CUT OFF ONE BRASS BOLT ON BACK OF PANEL -	.0015	S-3	M			.0015		.0017															
O	LAYOUT ALL NAME PLATE HOLES FOR DRILLING	EQ #4		V											.0351									
P	FIT PANEL INTO POSITION	EQ #10		V				.0166	.0070	.0031	.0084		.0136			.0158								
Q	SET BOX ON FLOOR	.0100	S-6	C					.0094	.0100	.0083			.0084										
R	TIE OR UNTIE TAGS	.0036	COMP. E. A.	C										.0053										
S	CUT ONE HOLE IN SIDE OF BOX, FINISH FILE, FIT COVER PLATE COMP.	.2907	S-7	M							.2907													
T	LAYOUT AND SAW ONE MOUNTING SUPPORT COMPLETE	.1249	S-7	M							.1249													
U	LAYOUT SIDE HOLE, CENTER PUNCH AROUND LAYOUT & PLACE TEMPLATE	.1360	S-8	M								.1360												
V	LAYOUT ONE HOLE FOR DRILLING	.0078	S-10	C								.0013	.0030	.0078	.0026									
W	CENTER PUNCH ONE HOLE	.0039	S-10	C								.0015		.0039	.0061									
X	CHALK MARK AROUND ONE PUNCH POINT	.0008	S-11	C								.0010			.0008									
Y	LAYOUT AND MARK ONE HOLE IN SIDE OF BOX	.0298	S-11	M											.0298									
Z	PUT IN SWITCH HANDLE COMPLETE	.0827	S-6	M						.0827														
A_1	PUT ON ONE PLATE AFTER HOLES ARE DRILLED	EQ #5 or #6		V						.0137	.0132													
B_1	FILE REAM ONE HOLE IN PANEL	.0144	S-4	M				.0144																

S-4: THESE OPERATIONS WERE SELECTED FROM A STUDY ON MOUNTING A CLINE CONTROLLER TO EKE OUT AVAILABLE DATA

S-7: NO PANELS FITTED PROPERLY SO MOUNTING TIME IS DISREGARDED ON THIS STUDY

FIG. 139.—Master table compiled for panel mounting formula.

Allowed Time:

See Sub A, Sub B, and Sub C of this formula.

Application:

This formula applies to laying out brackets in enclosing cabinets for drilling and to assembling panels in enclosing cabinets as done in section *F*-13 under conditions and with equipment as of May 1, 1926, except Cline Controllers.

Analysis:

The tools and accessories needed are screwdriver, pliers, socket wrenches, hammer, center punch, scribe, stiff wire 12 inches long, taps and holder, electric hand drill, drills, wire cutters (large and small), heavy iron riveting block, small metal block for riveting, round file, flat file.

The materials needed are nuts, bolts, flat washers, lock washers, rubber washers, studs, plugs for resistance frames, light and heavy rivets, name plates, trade marks.

The group leader gets all materials to the men, 5 per cent being allowed to cover his time.

All boxes and panels are kept in a stock pile close to work bench.

Panels are mounted in two different ways, on mounting studs and on mounting brackets. For convenience, the following subdivisions of the work may be made:

A. Assemble panel to box (when mounting studs are used).
B. Lay out all holes for drilling (when mounting brackets are used).
C. Assemble panel to box (when mounting brackets are used).

A subformula will be derived for each case.

Boxes and panels are brought to the stock pile by the move men. Group leader handles information and gets name plates stamped. Men working on layout and assembly have no other duties outside the actual work performed on boxes. Finished boxes are removed by move men.

Whenever electric hand drill is used, 0.0121 hour is allowed per box. This is allowed because with two men using the same drill, there is necessarily some delay in getting electric drill and putting in the proper size of drill.

Where template is used for laying out holes in cover, the time allowed will be the same as though a template were not used.

Tags come only on Type *F* or the *AC* apparatus since this is tested before assembly to box. The Type *C* being tested after assembly has no tag. Since the same size of box is used for both Type *F* and *C*, $\frac{0.0073}{2}$ or 0.0036 or one-half the time per tag will be allowed on every box for tying on tag.

In the larger sizes of boxes taking mounting studs, it is easiest to put the mounting studs in with the box on the bench and to put the panel in with the box on the floor. 0.0100 hour is to be allowed for setting box on floor.

Time for file reaming holes is to be allowed only when holes in box are not laid out, using panel to be assembled as template.

Boxes with Screen Sides. Cline Controllers:

At present, only one style of box is built up in *F*-13, only two different styles of resistance frames are made, and only two differant styles of screen-sided boxes used. These are all used for the two types of Cline Controllers.

The time values for these jobs may be set by time study rather than by formula. Certain operations, occurring only in this work, would have to be represented by a number of symbols in the formula. This would give a long unwieldy looking expression, about half of which might never be used if no new work of this type were introduced into the shop.

Therefore, studies on this work will not be used in compiling the formulas but will be kept for reference in case sometime in the future other work of a similar nature comes along.

Special Side Holes on Navy Jobs:

Navy jobs require that a hole be cut in either side of box for leads. These holes are covered with plates to protect the interior of the box from dust, etc. when hole is not used. The time required to lay out, finish, and fit up such a hole is covered by operations *S* and *U* in Table of Details.

The only standard box in which these holes are cut at the present time is the box covered by Drawing 371902. In this case the mounting brackets have to be sawed to fit. Operation *T* takes care of this.

It will not be necessary to carry these values in the formula, but they will be left in the Table of Details to be available for reference.

General Practice for Putting Name Plates on Boxes:

No hard and fast rules may be laid down for putting name plates on boxes, but the following is the general practice. In any doubtful case, the actual practice should be checked from the floor.

There are three types of name plates:

1. Circular trade mark (2 or 4 holes).
2. Instructions for ordering renewal parts (4 holes).
3. Name plate giving capacities, *S* No., *S. O.* No., Serial No., etc. (2 or 4 holes).

Cline Controllers take no name plate of any sort on box.

All other boxes with covers take the trade-marks. The size of trade marks used is proportional to the cover area. The group leader has a table of the proper size to use. The larger trade marks from 4 inches in diameter up have 4 holes.*

Small boxes containing single-unit panels take the trade mark only.

All boxes other than Cline and the above small boxes take the instruction plate.

Boxes without covers take the instruction plate only, mounted on one side of the box.

The general name plate (3) is mounted on the panel whenever possible. When there is no room on the panel, the name plate is mounted on the box

These general rules apply to all standard boxes.

* These four-hole trade marks are used on covers larger than 600 square inches.

TIME STUDIES

Study Number	Date	Time Study Taken by
S-1 —1	4-4-24	H. B. M.
S-2 —2	4-4-24	"
S-3 —4	4-4-24	"
S-4 —1	4-5-24	"
S-5 —2	4-5-24	"
S-6 —3	4-5-24	"
S-7 —3	4-8-24	"
S-8 —2	4-7-24	"
S-9 —1	4-9-24	"
S-10—1	4-8-24	"
S-11—3	4-4-24	"
S-12—5	4-4-24	"
S-13—2	4-9-24	"
S-14—1	4-11-24	"

TABLE OF DETAIL OPERATIONS

Symbol	Operation Description	Decimal Hours	Reference
A	Put in one mounting stud complete	Eq. 1	
B	Put on one name plate complete	Eq. 2 or 3	
C	Prepare electric hand drill	0.0121	S-1
D	Place one rubber washer on stud	0.0026	S-3
E	Place panel in box	Eq. 7	
F	Bolt panel to mounting stud, time per stud	0.0080	Computed
G	Put on one cover lock	0.0550	Computed
H	Remove box	0.0049	S-7
I	Chalk areas or mark holes for filing	0.0116	S-11
J	Put in one bolt with wrench	0.0108	S-2-4
K	Remove panel from box	Eq. 8	
L	Get box	0.0075	S-3
M	Get panel from or remove panel to stock pile	Eq. 9	
N	Cut off brass bolt on back of panel	0.0015	S-3
O	Lay out all name plate holes for drilling	Eq. 4	
P	Fit panel into position	Eq. 10	
Q	Set box on floor	0.0100	S-6
R	Tie or untie tags, etc	0.0036	Computed
S	Cut one hole inside of box, finish file and fit cover plates complete	0.2907	S-7
T	Lay out and saw one mounting support complete	0.1249	S-7
U	Lay out side hole, center punch around, lay out and place template	0.1360	S-8
V	Lay out one hole for drilling	0.0028	S-10
W	Center punch one hole	0.0039	S-10
X	Chalk mark around one punch point	0.0008	S-11
Y	Lay out and mark one hole in side of box	0.0298	S-11
Z	Put in switch handle complete	0.0827	S-6
A_1	Put on one name plate after holes are drilled	Eq. 5 and 6	
B_1	File ream one hole in panel	0.0144	S-4

Synthesis:

Equations to be Used in Connection with Formula.

Time for putting in one mounting stud complete in hours =

$$0.0119 + 0.000028P \quad \text{Eq. 1}$$

Time for putting on name plates complete on panels up to 375 square inches in area =

$$0.0186N_1 + 0.0112N + 0.000009 \times P \times N \quad \text{Eq. 2}$$

Time for putting on name plates complete on panels above 375 square inches in area =

$$0.0186N_1 + 0.0196N \quad \text{Eq. 3}$$

Time for laying out holes for name plates only, in hours =

$$0.0186N_1 + 0.00225N \quad \text{Eq. 4}$$

Time to put on name plates after holes are drilled, panels up to 375 square inches in area =

$$0.00585N + 0.000009\ P \times N \quad \text{Eq. 5}$$

Time to put on name plates after holes are drilled, panels above 375 square inches in area =

$$0.01425N \quad \text{Eq. 6}$$

Time to place panel in box, in hours =

$$0.0095 \times M \quad \text{Eq. 7}$$

Time to remove panel from box, in hours =

$$0.0035 \times M \quad \text{Eq. 8}$$

Time to get panel, in hours =

$$0.0053 + 0.000031P \quad \text{Eq. 9}$$

Time to fit panel into position, in hours

$$0.00035P - 0.0020 \quad \text{Eq. 10}$$

where M = number of men performing the operation.
N = number of holes in name plate.
N_1 = number of name plates.
P = panel area in square inches.

Also see subformulas.

Inspection:

After assembly cabinets are inspected to see that panels are firmly and properly placed, that box is complete in all its parts, that cover fits, and that proper name plates are in place.

Payment:

Standard-time group plan.

Approved:

Time-study Supervisor | Time-study Department

Formula F-13 No. 7-A.
May 1, 1926.

Part:

Enclosing cabinets or boxes in which mounting studs are used.

Operation:

Assemble panel to cabinet, put on all name plates complete.

Work Station:

Bench.

Allowed Time:

$0.0314 + 0.0550C + 0.0095M + 0.0112N + 0.0186N_1 + 0.000066P + 0.000009PN + 0.000028PY + 0.0015R + 0.0225Y$ for panels up to 375 square inches.

$0.0414 + 0.0550C + 0.0095M + 0.0196N + 0.0186N_1 + 0.000066P + 0.000028PY + 0.0015R + 0.0225Y$ for panels above 375 square inches in area,

where C = number of cover locks put on.
M = number of men required to handle panel.
N = number of holes in all name plates put on.
N_1 = number of name plates.
P = Area of panel in square inches.
R = number of brass connection bolts on back of panel which must be cut off.
Y = number of mounting studs.

Application:

This subformula applies to all work of assembling panel to cabinet, done in F-13 at the present time, where panel is mounted on mounting studs.

Procedure:

Get box, place mounting studs in box, put rubber washers on studs (if large box, set on floor), get panel, place panel in box, fit in place, bolt panel to mounting studs, prepare electric hand drill, put on name plates as specified, put on cover lock if specified, and if necessary, cut off brass connection bolts on back of panel before assembling.

Synthesis:

$C + H + L + R +$ [constant from Eq. (9)] $-$ [constant from Eq.(10)] $= 0.0121 + 0.0049 + 0.0075 + 0.0036 + 0.0053 - 0.0020 = 0.0314$ = constant for panels up to 375 square inches in area.

Above constant $+ Q = 0.0314 + 0.0100 = 0.0414$ = constant for panels above 375 square inches in area.

Above constants + Eq. (1) + Eq. (2) or (3) + Eq. (7) + Eq. (9) + Eq. (10) $+ G + N$ = formula expressions given under Allowed Time.

A = Eq. (1) $-$ put in one mounting stud complete $= 0.0119 + 0.000028P$. Time-study values of time to put in one mounting stud, plotted against panel area, gives a straight line. The above equation is the algebraic expression for this line.

B = Eq. (2) or (3) $-$ place on name plates complete $= 0.0186N_1 + 0.0112N + 0.000009PN$ for panels up to 375 square inches in area and

$0.0186N_1 + 0.0196N$ for panels above 375 square inches in area. Curves were plotted from time-study data of time to scribe holes *versus* number of holes, time to center punch holes *versus* number of holes, time to lay on name plate and two rivets *versus* panel area. The algebraic expression for each curve was found. The time to drill holes, cut off rivets, and rivet rivets was derived from the data expressed in terms of N. The summation of those algebraic quantities plus a constant for layout position of name plate (per name plate) gives the above equations.

E = Eq. (7) − place panel in box = $0.0095M$. The time to place panel in box was found to be fairly constant. Twice this constant time is allowed when it requires two men to handle the panel.

M = Eq. (9) − get panel = $0.0053 + 0.000031P$. This expression was found by plotting time to get panel *versus* panel area. The larger panels are heavier and hence harder to carry to the bench than the smaller.

P = Eq. (10) − fit panel in place = $0.000035P - 0.0020$. This expression was found by plotting time to fit panel in place *versus* panel area. When the panel area falls under 58 square inches, the panel is considered to be so light that fitting time is negligible and hence below $P = 58$, Eq. (10) is omitted from the formula.

Inspection:

After assembly cabinets are inspected to see that panels are firmly and properly placed, that box is complete in all its parts, that cover fits, and that proper name plates are in place.

Payment:

Standard-time group plan.

Approved:

______________________	______________________
Time-study Supervisor	Time-study Department

Formula F-13 No. 7-B.
May 1, 1926

Part:

Enclosing cabinets or boxes in which mounting brackets or mounting lugs are used.

Operation:

Lay out all holes for drilling.

Work Station:

Bench.

Allowed Time:

$0.0346 + 0.0130M + 0.00233N + 0.0186N_1 + 0.000062P + 0.0298S + 0.0067X$,

where M = number of men required to handle panel.
N = number of holes in all name plates.
N_1 = number of name plates.
P = panel area in square inches.
S = number of holes laid out for switch handles.
X = number of mounting brackets or lugs.

Application:

This formula applies to all layout work on boxes using mounting supports or lugs as done in F-13 at this time.

Procedure:

Get box, chalk brackets or lugs, get panel, place panel in box, scribe holes, remove panel from box, center punch holes, lay out all name-plate holes, chalk circle around each name-plate hole, punch mark, remove panel, remove box, and lay out and mark one hole for switch handle in side of box.

Synthesis:

$H + I + L + 2 \times$ constant from Eq. (9) $= 0.0049 + 0.0116 + 0.0075 + 0.0106 = 0.0346 =$ constant per box.

$0.0346 +$ Eq. (4) $+$ Eq. (7) $+$ Eq. (8) $+$ Eq. (9) $+ Y + X$ (number of name-plate holes) $=$ formula expression given under Allowed Time.

$O =$ Eq. (4) $-$ lay out all name-plate holes for drilling $= 0.0186N_1 + 0.00225N$. This equation is simply that part of Eq. (2) or (3) which takes care of layout position of name plate, scribe holes and center punch holes. See Synthesis Formula F-13 No. 7-A.

$K =$ Eq. (8) $-$ remove panel from box $= 0.0035M$. The time to remove a panel from a cabinet was found to be fairly constant. When two men are required to handle the panel, twice as much time is allowed.

For explanation of E and M, or Eqs. (7) and (9), see Synthesis Formula F-13 No. 7-A.

Inspection:

No inspection after this operation.

Payment:

Standard-time group plan.

Approved:

Time-study Supervisor	Time-study Department

Formula F-13 No. 7-C.
May 1, 1926.

Part:

Enclosing cabinets or boxes in which mounting brackets or mounting lugs are used.

Operation:

Assemble panel to cabinet, rivet on name plate.

Work Station:

Bench.

Allowed Time:

$0.0193 + 0.0550C + 0.0827H + 0.0095M + 0.00585N + 0.000066P + 0.000009PN + 0.0015R + 0.0229X + K \quad (0.0116 + 0.0144F + 0.0130M)$ for panels up to 375 square inches in area.

$0.0193 + 0.0550C + 0.0827H + 0.0095M + 0.01425N + 0.000066\,P + 0.0015R + 0.0229X + K(0.0116 + 0.0144F + 0.0130M)$ for panels above 375 square inches in area,

where C = number of cover locks put on.
F = number of holes file reamed.
H = number of switch handles mounted complete.
K = use as special value when conditions make it necessary to lay out holes other than from the panel to be mounted.
M = number of men required to handle panel.
N = number of holes in all name plates.
P = area of panel in square inches.
R = number of brass connection bolts on back of panel which must be cut off.
X = number of mounting brackets or lugs.

Application:

This formula applies to all work of assembling panel to cabinet as done in *F*-13 at this time, where the panel is mounted on mounting brackets or lugs, except Cline Controllers.

Procedure:

Get box, get panel, place panel in box, fit in place (chalk holes for filing, remove panel, file ream holes, and replace panel if necessary), place rubber washers under holes, put in holding-down bolts, put on name plates (put on cover lock, put on switch lever, if necessary), tie on tag, and remove box.

Synthesis:

$H + L + R$ + (constant from Eq. (9)) − (constant from Eq. (10)) = $0.0049 + 0.0075 + 0.0036 + 0.0053 - 0.0020 = 0.0193$ = constant for each panel mounted on mounting brackets.

Above constant $+ G + I + B_1$ + Eq. (5), or Eq. (6) + 2 Eq. (7) + Eq. (8) + Eq. (9) + Eq. (10) = formula expression given under Allowed Time.

For E, K, M, and P or Eqs. (7), (8), (9), and (10), see Synthesis, Formula *F*-13 No. 7-*A*.

A_1 = put in name plate after holes are drilled = Eqs. (5) or (6) = $0.00585N + 0.000009PN$ or $0.01425N$ for panels up to or above 375 square inches in area, respectively. These equations are simply those parts of Eqs. (2) and (3) which take care of lay on name plate and rivets, cut off two rivets, and rivet two rivets. See Synthesis, Formula *F*-13 No. 7-*A*.

Inspection:

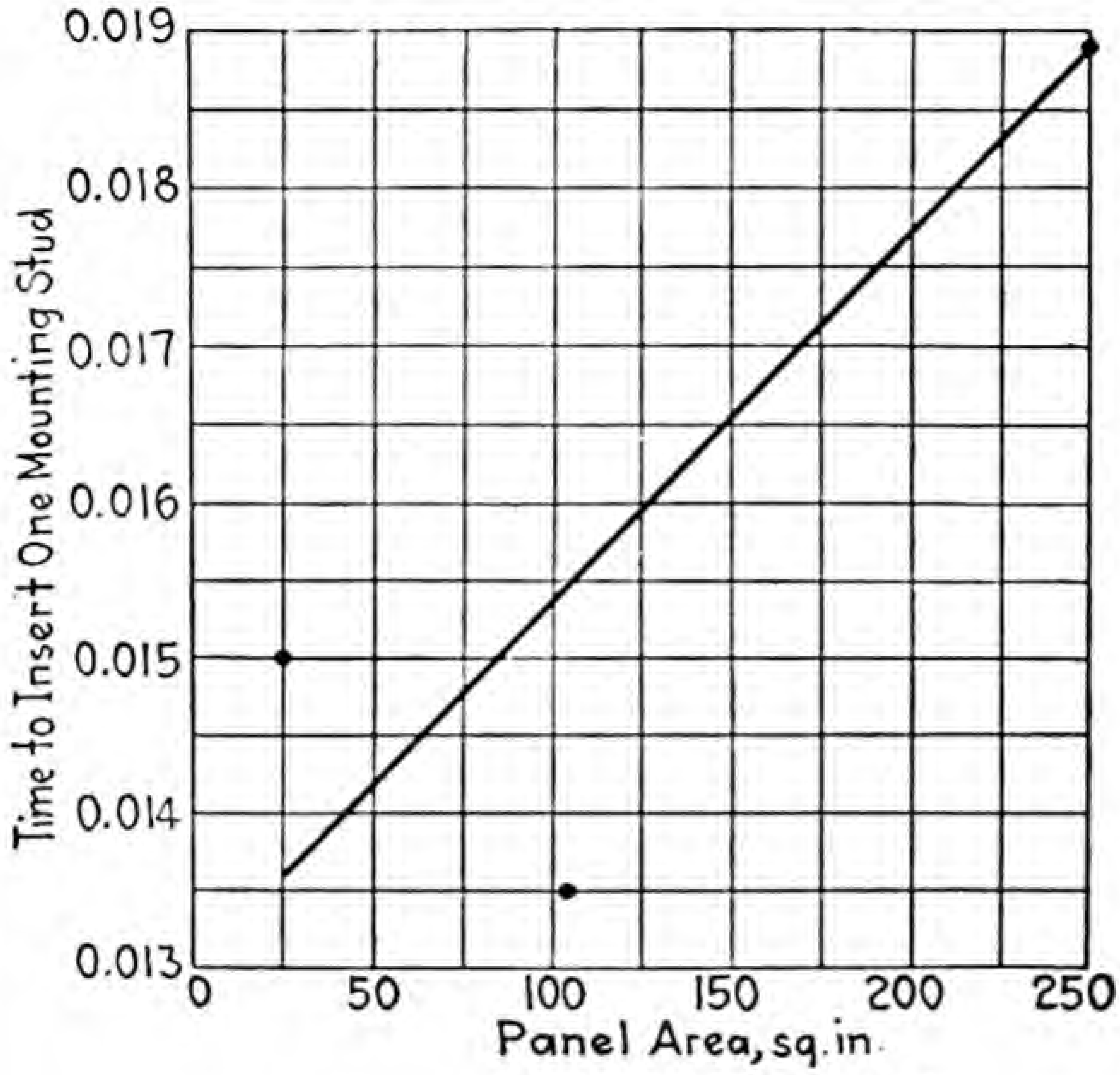
After assembly, cabinets are inspected to see that panels are firmly and properly placed, that the box is complete in all its parts, that cover fits, and that proper name plates are in place.

Payment:

Standard-time group plan.

Approved:

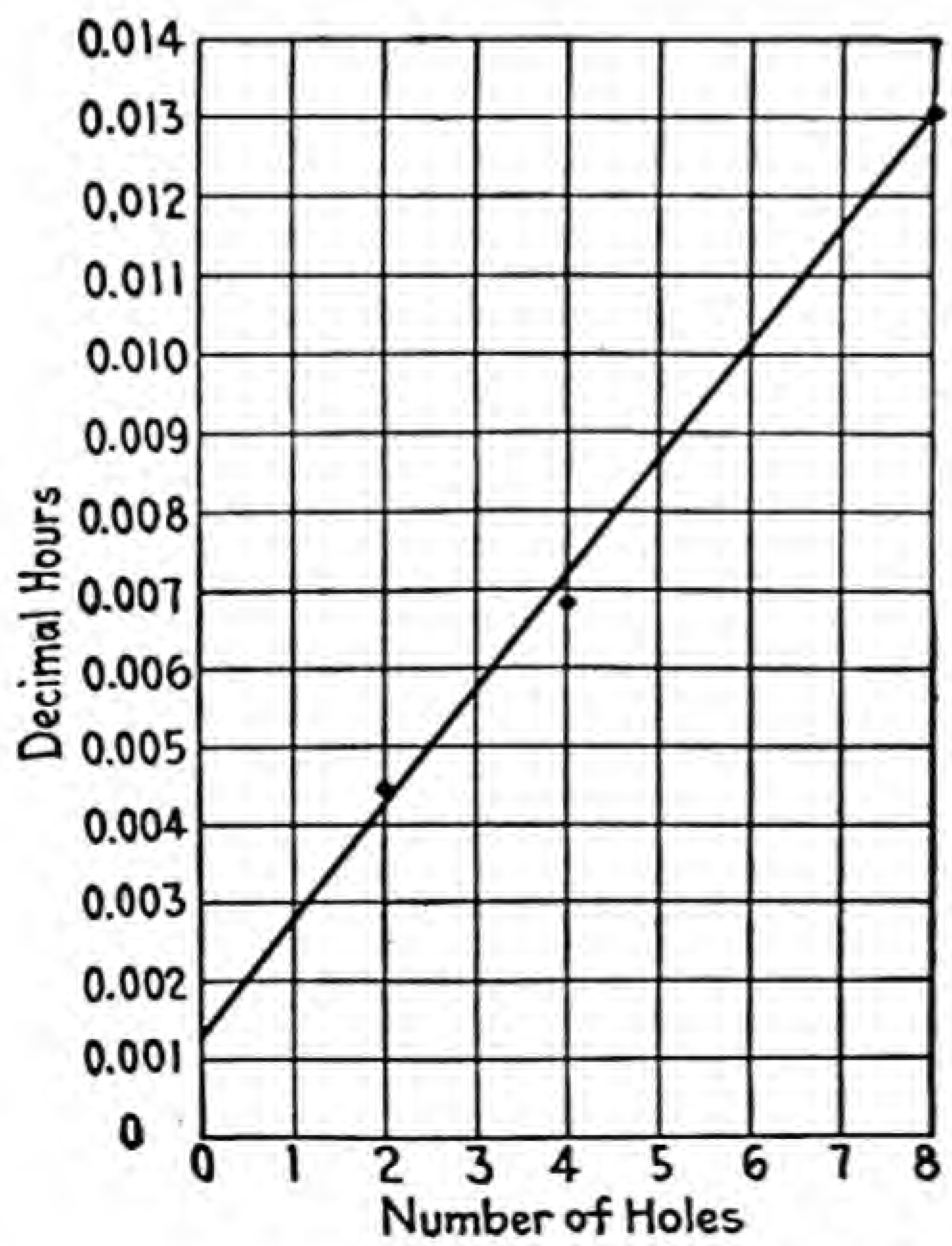
Time-study Supervisor   Time-study Department



Panel Area vs. Time to Insert Mounting Studs.

Reference:
S-1, S-2, S-5 and Element Analysis.

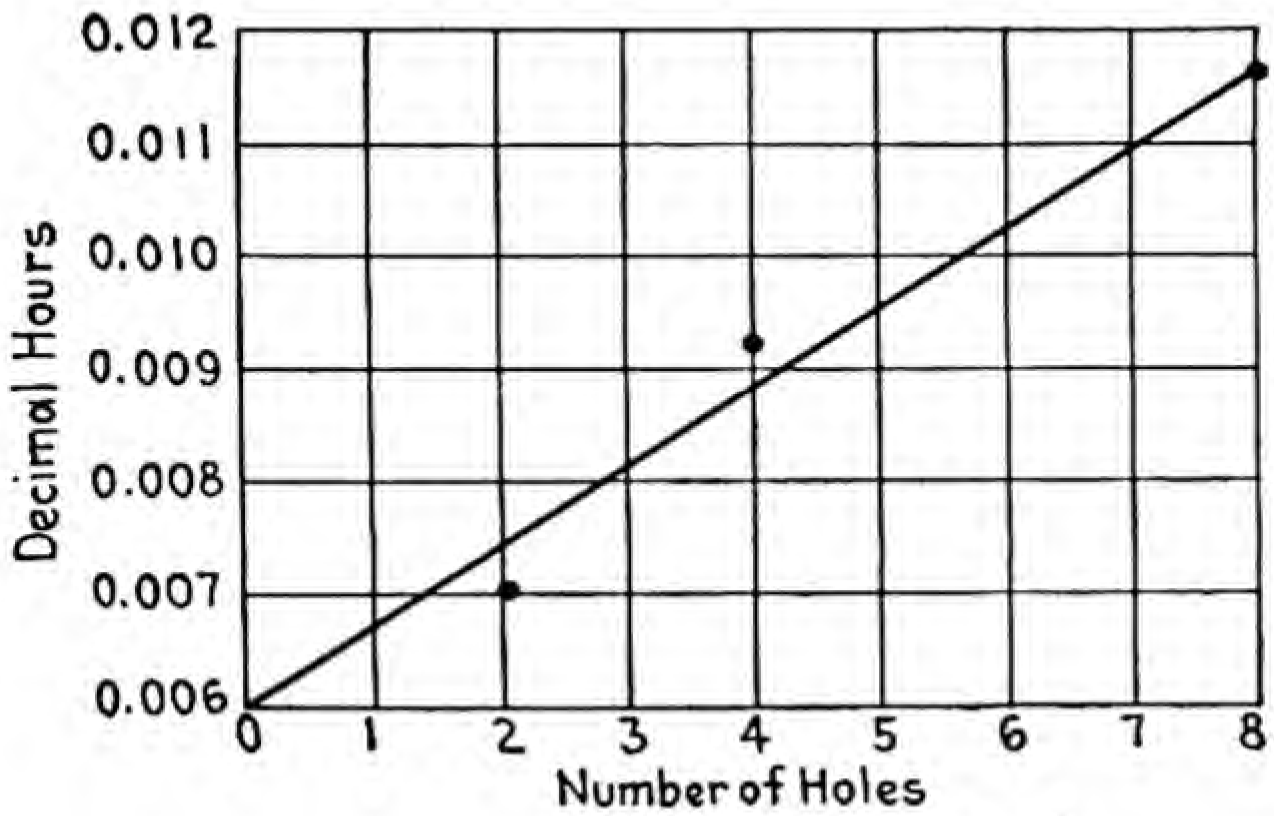
CURVE 1.



Number of Holes vs. Scribing Time.

Reference:
S-5 and S-11.

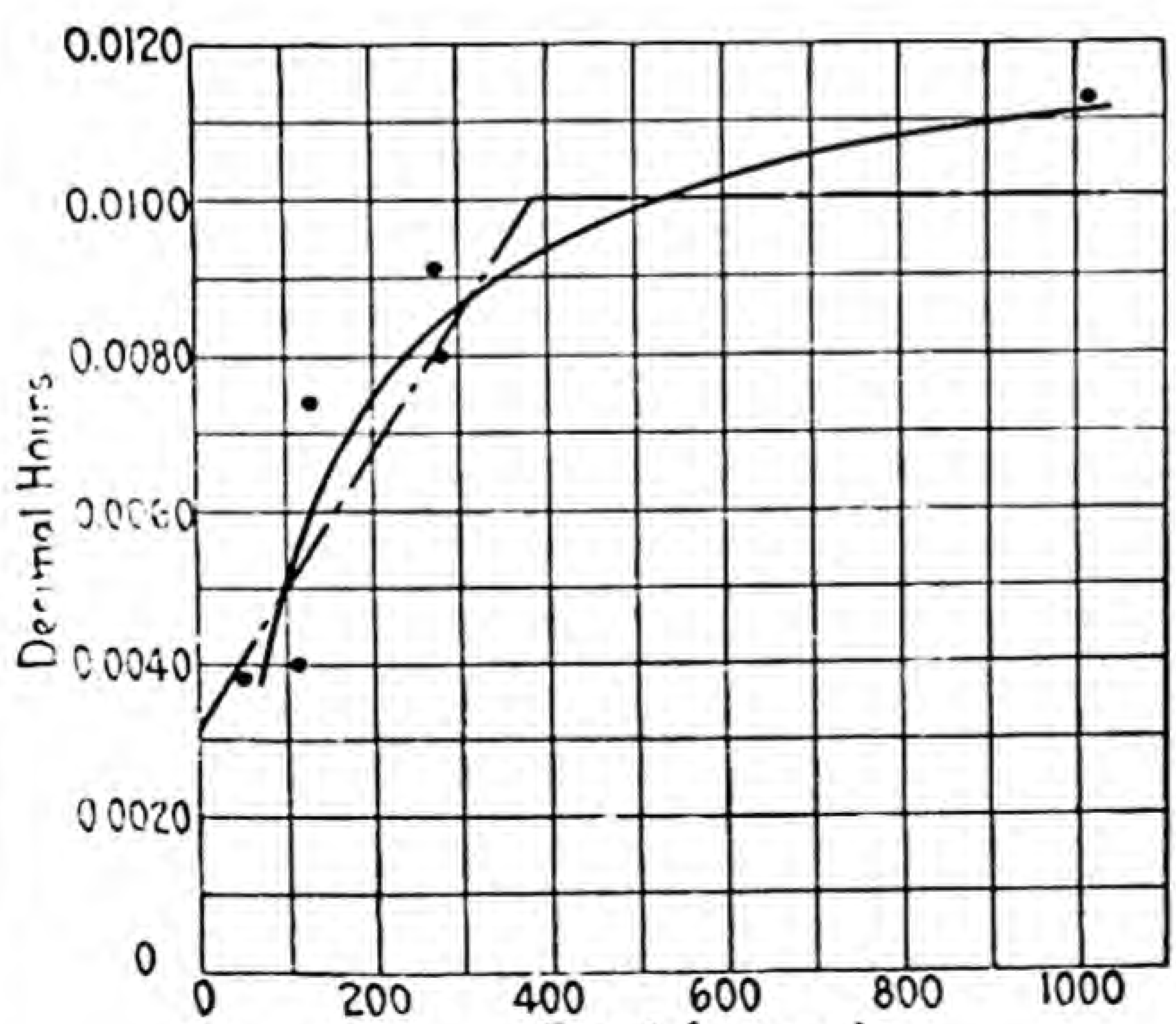
CURVE 2.



Number of Holes vs. Time to Center Punch.

Reference:
S-5 and S-12.

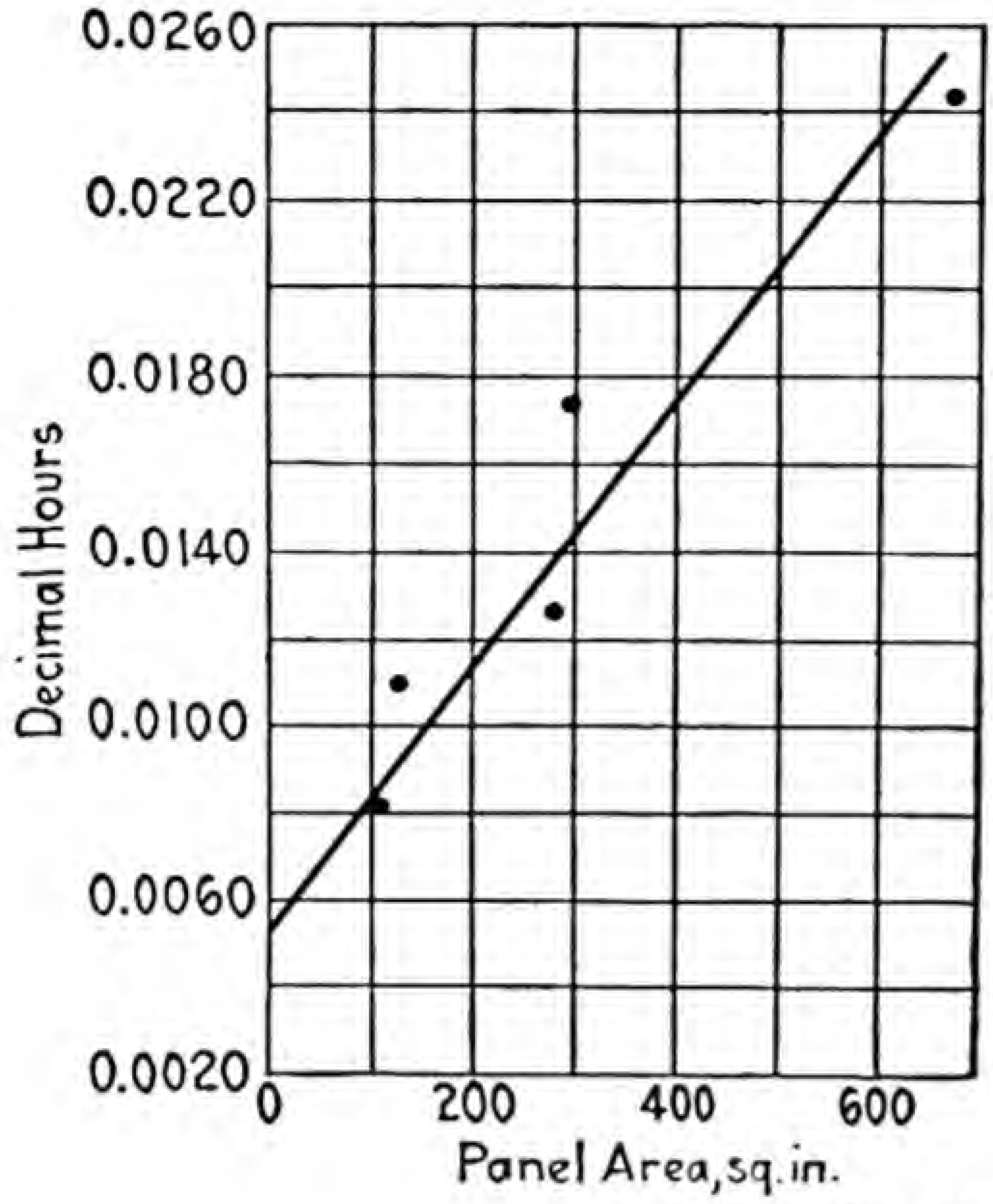
CURVE 3.



Panel Area vs. Time to Place Name Plate and Rivets.

References:
S-1, S-3, S-5, S-6, S-7 and S-12.

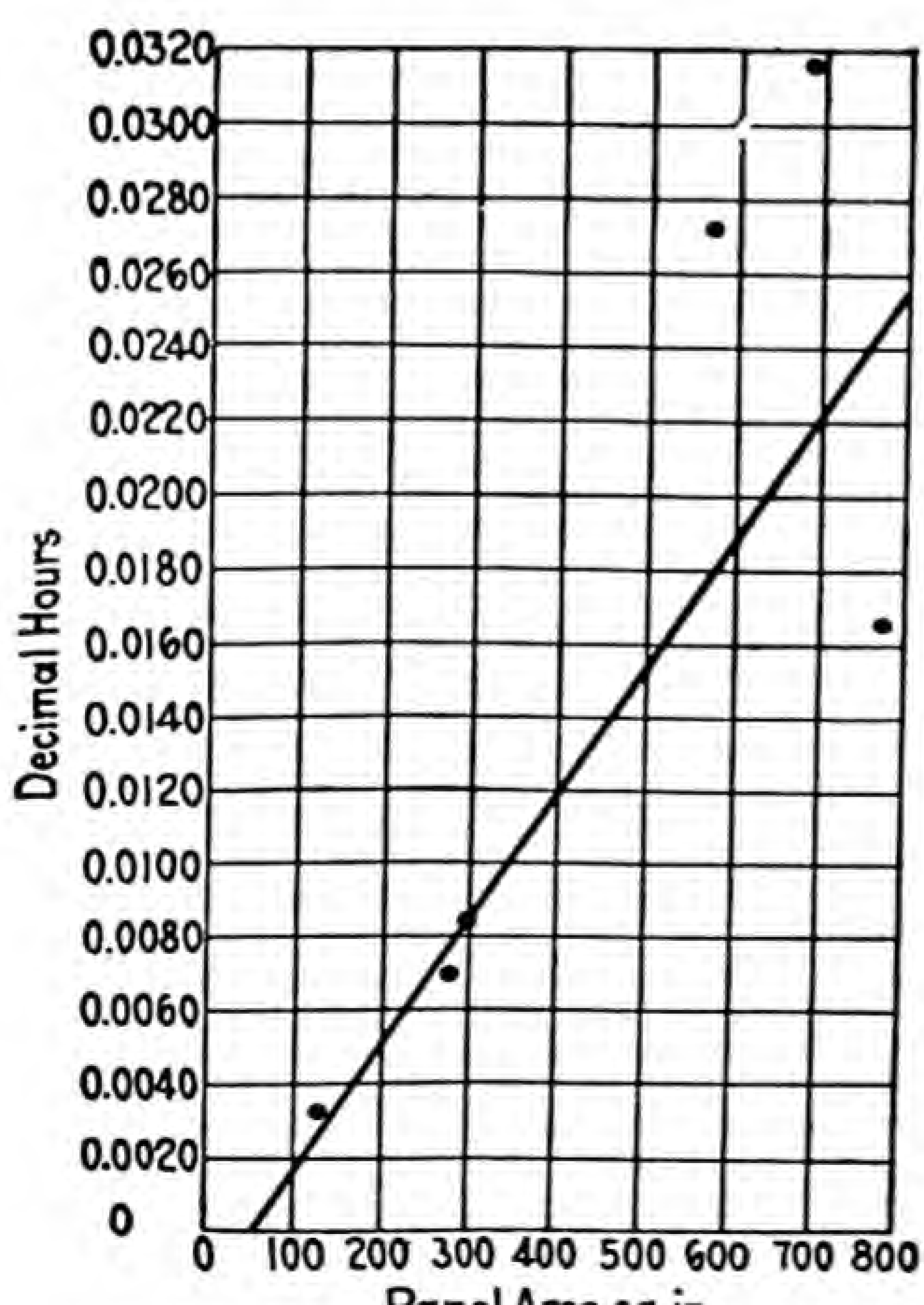
CURVE 4.



Panel Area vs. Time to Get Panel.

References:
S-3, S-5, S-6, S-7 and S-12.

CURVE 5.



Panel Area vs. Fitting Time.

References:
S-4, S-5, S-6, S-7, S-9 and S-12.

CURVE 6.

CHAPTER XXXIV

FORMULA FOR ENGINE LATHE

Almost everyone who has had any experience with incentive plans has recognized the fact that it is easier to set time allowances for machine work than it is for the so-called handwork. The reason for this is that the machine is much more definite and constant than man. Machine-tool builders and cutting-tool manufacturers conduct tests to determine the possibilities of their product and supply this information to their customers. There are any number of mechanical handbooks that contain data about the performance of machine and cutting tools. This information and the experience gained on a particular application make possible the establishing of fairly accurate machining time. However, while much of the judgment has been eliminated in machining practice, there are still possibilities for considerable error. Nearly all of the machining data given in handbooks and supplied by tool builders have been obtained under test conditions and cannot be used in a general way, but they do serve as an excellent guide. Obviously parts that are frail and that extend out relatively far from the point of support cannot stand the speed and feed that a solid block can. It is necessary, therefore, to determine good practice for particular conditions.

Machining formulas were compiled at first largely in standard data form. It was necessary for the time-study man either to follow the operation through mentally or go out to the machine and obtain a list of the detailed operations. He then substituted time values for each detail operation from his standard data, as explained in Chap. XXIII, and obtained cutting time by making an actual check with a stop watch. This method proved cumbersome, and eventually it was found possible to combine all handling operations into a formula by means of which the time to be allowed for machine and part handling could be computed easily and quickly from the drawing plus a good general knowledge of the work, and the necessity of making a list of detail operations was eliminated. This was a step toward increased efficiency, but

it was still necessary to obtain cutting time from an actual stop-watch check. The disadvantages of this were obvious. It was impossible to establish time values on new work until the job was partly completed; an experienced operator might be able to convince an inexperienced time-study man that he was using maximum feeds and speeds during the check, which was not always the case, and the time-study man still had to spend considerable time in going out on the floor and making checks. On complicated jobs, the time required for this was considerable, and the time-study man often found it possible to establish only four or five time values during the course of the day. This condition was not so serious in shops where the work was more or less standard and the number of new jobs coming through daily small; but in the case of job shops where quantities were small and the work almost non-repetitive, it was evident that a quick, accurate method of establishing time allowances on cutting time would have to be devised or the putting of such work on an incentive basis would have to be done by estimating—always an unsatisfactory method.

Accordingly, a careful study of all of the variables which affect cutting time was made, and it was eventually found possible to construct a number of charts, thus enabling the time-study man to establish time allowances on cutting time directly from the drawing without the necessity of visiting the machine. High-grade analysis was needed to reach this end, and the construction of the charts called for a good deal of detail work by one thoroughly familiar with machining feeds and speeds; but once the charts were constructed, their application was a comparatively simple matter. The method followed in constructing the charts is explained in detail in the formula example given below.

The shop for which the following formula was compiled specialized on the machining of a great variety of brass parts. The average lot size received was three pieces; and the maximum, eliminating exceptional cases, six. With the engine-lathe formula given below, however, one time-study man was able to establish time values in advance for about ten operators in half a day's time. Without the formula, he would have been forced to resort to estimating, even though he had a set of standard data, for the nature of the work was so complex that accurate analysis and stop-watch checks were out of the question in the time available for establishing these time values. In other words, it was essential that he have a formula in which he could substitute values taken

directly from the drawing and arrive at the allowed time with a minimum of effort and analysis on his part.

The engine-lathe formula given and similar formulas have been in actual use for several years, and the results obtained have amply demonstrated their accuracy. The example given covers the machining on engine lathes of only non-ferrous metals, but similar formulas have been derived for the ferrous metals as well. In application, the formula given is limited to quantities of six pieces. It is obvious that where quantities are small, the operators do not have a chance to become as efficient and to devise so many time-saving practices as when quantities are larger. The formula was therefore based on the average lot size received and strictly limited in application, so that if in the future quantities increased, a further study could be made without question on the part of the operators. The same principle of compiling machining-time charts, however, can be followed regardless of quantities, provided that the charts are based on a study of the conditions to which they are to apply.

Formula Non-ferrous Engine Lathe.
July 1, 1929.

Part:

Brass, bronze, and aluminum castings and bar stock.

Operation:

Drill, bore, ream, turn, face, chamfer, radius, counterbore, groove, chase polish, and cut-off.

Work Station:

16-, 18-, and 24-inch engine lathe and 18-inch Fox lathes (*E*-194, *E*-195, *E*-972, *E*-973, *E*-986, *E*-987, *E*-1407, *E*-1548, *E*-1554, *E*-1565, *E*-1566, *E*-1693, *E*-1695, *E*-1699, *E*-1709 and *E*-1969).

Allowed Time:

Set-up.—$0.365 + 0.0186A + 0.0480B + 0.0824C + 0.0122D + 0.0399E + 0.1501F + 0.0770G$.

Each-piece Time.—$0.0153 + 0.0694H + 0.0185I + 0.0574J + 0.0769K + 0.0078L + 0.0059M + 0.0147N$ + Table I + Table II + Table III + Table IV + Table V + Table VI + Table VII + Table VIII + 0.0035 small part + 0.0079 medium part + 0.0568 crane part.

where A = use when compound is turned to angle.

B = use when steady rest is used on 16- or 18-inch lathe.

C = use when steady rest is used on 24-inch lathe.

D = number of tools obtained from tool crib.

E = number of forged tools or Armstrong tool holders used (except threading tools).

F = number of threading tools used.
G = use when stop clamps are used.
H = use when large boring bar is used.
I = number of times steady rest is moved.
J = use when independent chuck is used on 16- or 18-inch lathe.
K = use when independent chuck is used on 24-inch lathe.
L = number of times steady rest is opened and closed.
M = use when draw chuck is used.
N = use when universal chuck is used.

TABLE I.—MISCELLANEOUS OPERATIONS

Operation	Decimal Hours
Screw on and remove small part from threaded jig....	0.0092
Screw on and remove medium part from threaded jig	0.0247
Put on and remove small part from plug............	0.0055
Put in and remove small part from pot jig..........	0.0145
Use when jig for diffusers is used..................	0.0790
Clamp and remove part from diffuser jig............	0.0607
Use when threaded jig is used on spindle............	0.0489
Use when large angle plate is used................	0.2631
Chuck and true up long part 24-inch lathe, over 20 inches long....................................	0.1798
Tighten chuck 16- or 18-inch lathe and tap part against stop clamps, where part does not require truing up....................................	0.0174
Change chuck for face plate, or *vice versa*, 24-inch lathe	0.0567
Set scale and stop for measuring..................	0.0109
Set taper attachment............................	0.0692
Use when ring clamp is used......................	0.0353
Use when pipe center is used......................	0.0348
Straighten valve stem.....	0.0287
Fit valve to cage................................	0.0816
Remove chuck 18-inch engine lathe......	0.0106

TABLE II

Operation	Decimal Hours
True up part when in halves 4¼ inches in diameter by 7 inches long..................................	0.0434
Set inside micrometer...........................	0.0105
Make small threaded plug........................	0.2494
Square out corner...............................	0.0068
File smooth or burr with scraper (per job)..........	0.0074
Chamfer ⅛ inch or less..........................	0.0034
Make straight plug for bushings...................	0.1521
Radius	
⅛ inch..................................	0.0095
¼ inch..................................	0.0190
½ inch..................................	0.0380
Polish per inch diameter or under.................	0.0095

Note: Time for machining radii or polishing diameters over 4 inches must be obtained from floor by time study.

Small Parts: Up to 25 pounds and 88 cubic inches of volume.

Medium Parts: From 25 to 50 pounds and from 88 to 180 cubic inches of volume.

Crane Parts: Over 50 pounds.

These sizes and weights are only approximate, and judgment should be used in applying them to parts of unusual size and shape.

Job Characteristics:

Strong Machining Conditions.—Jobs of a rigid nature that can be held firmly without danger of breaking or pulling out of chuck, having a good chucking grip whereby it is possible to use high speeds and take two roughing cuts, job or tool will have an overhang up to 4 inches.

Medium Machining Conditions.—Jobs that can be held firmly and that will not pull out of chuck using high speeds and three roughing cuts, having an overhang which ranges from 4 to 8 inches. In boring, the tool will have an overhang from 4 to 8 inches.

Weak Machining Conditions.—Jobs that cannot be held firmly in chuck, with thin section, weak construction, or excessive overhang. Jobs of this kind require four or more roughing cuts.

Finish Required:

The finish required is the finish specified on the drawing, which may be rough finish, finish, or fine finish.

Accuracy:

The accuracy desired is shown by the tolerances specified on the drawing. It is obvious that the degree of accuracy necessary is a governing factor in the number of cuts taken on a job. A study of this condition has resolved itself into three different classes.

First.—A job with standard drawing tolerances ranging from ± 0.010 to ± 0.062 inch requires a minimum number of cuts.

Second.—A job with a tolerance of ± 0.003 to ± 0.010 inch, which would require additional cuts.

Third.—A job with a tolerance of ± 0.000 to ± 0.003 inch, which would require a maximum number of cuts.

The number of cuts allowed for each class and each job characteristic is shown on Tables III and IV.

Material Groups:

The various materials have been divided into four different groups according to their cutting characteristics:

Group 1.—Consists of aluminum and different grades of babbitt.

Group 2.—Consists of ordinary bronze, bearing bronze, and ordinary grades of brass.

Group 3.—Consists of naval brass, phosphorous bronze, manganese bronze, naval bronze, valve bronze, and government gun metal.

Group 4.—Consists of gun metal and Perkins metal.

Elemental Constant:

The constant for boring, turning, facing, grooving, and parting includes time for changing feeds, speeds, locking and unlocking carriage, setting cutting tool, setting cuts, gaging time, engaging and releasing feed, and starting and stopping machine. The constants will vary with the number of cuts that are allowed, which will vary with each job characteristic. The constant is to be allowed once every time the machining constant is used, except where a number of operations can be done with the same tool, set in the same position, as is done on certain packing rings. Where groove, face, and counterbore are done in this manner, only one elemental constant is allowed.

Analysis of the Construction of the Cutting Charts:

The cutting charts have been derived from an analysis of machining time. The controlling variables are as follows:

Machining Conditions.—The machining conditions, namely, nature of job, overhang of tools, strength of section, and means of clamping or chucking, have been taken care of by classification and are tabulated under Job Characteristics. This classification is empirical. Actual observation on a variety of work shows justification for allowing two roughing cuts on "strong" jobs, three roughing cuts on "medium" jobs, and four roughing cuts on "weak" jobs.

The speed, feed, and number of finishing cuts are held constant. Some variance of opinion may be held as to this course, due to the difference between calculated speeds and feeds and obtainable speeds and feeds. But to offset this difference, it must be remembered that within certain limits, speed, feed, and depth of cut are directly related and that as one is decreased it is possible to increase either or both of the other.

Materials.—The various materials have been grouped according to their cutting characteristics (see data under Material Groups).

Dimensions.—The dimensions are taken from the drawing.

Finish.—The finish desired is specified on the drawing, the number of cuts required varying according to its refinement (see data under Finish Required).

Accuracy.—The accuracy required is specified on the drawing, the number of cuts required varying according to its degree (see data under Accuracy).

Stock.—The average amount of material to be removed on the prevailing line of work is about $\frac{1}{4}$ inch on a side. Therefore, the machining constants have been calculated for the removal of this amount of material. Where the amount of material to be removed exceeds $\frac{1}{4}$ inch on a side, a special value should be established and the cause of this condition investigated. The special value will be determined by the number of extra cuts to be taken. Constant for extra cuts will be found in Table III.

With all these foregoing variables occurring on every job, the following equation was derived to calculate the total cutting time:

Constants:

Total cutting time = (length of cut) × (time per inch) × (*f*) number of cuts.

$$\text{Time per inch} = \frac{\dfrac{0.0167}{\text{cutting speed}}}{\text{diameter} \times \dfrac{\pi}{12} \times \text{feed.}}$$

$$\text{Total cutting time} = (\text{length of cut}) \times \frac{\dfrac{0.0167}{\text{cutting speed}}}{\text{diameter} \times \dfrac{\pi}{12} \times \text{feed.}} \times (f)\ \text{No. of cuts.}$$

$\frac{\pi}{12} = 0.262.$

$\frac{0.0167}{0.262}$ is a constant.

(Length $\times$ diameter) is taken from drawing.

$\frac{1}{\text{Cutting speed} \times \text{feed}}$ varies with material and machining conditions.

(f) is a function of the number of cuts required to machine to size.

The machining constants in Tables III and IV were derived from this equation and are based on the speeds, feeds, and number of cuts shown in Tables IX and X. These constants when multiplied by the length of cut and the cutting diameter will give the total cutting time required to machine each size.

Table III is based on the removal of ¼ inch on a side.

Table IV is based on the width of cut.

Table V is a drilling chart for the different groups of materials and is based on the speeds and feeds shown in Table XI. The speeds and feeds used are the speeds and feeds obtainable on the machines. The time values include time for the lead of drill, change speed, center, start and stop machine, tail-stock travel, put on and remove sleeve on drills, put tool in tail stock, and remove.

Table VI is a reaming chart for the different groups of materials and is based on the speeds and feeds shown in Table XII. The speeds and feeds used are the speeds and feeds obtainable on the machines. The time values include start and stop machines, change speed, put on and remove sleeve, put tool in tail stock and remove, tail-stock travel, tighten and loosen tail stock, and lubricating time.

Table VII is a combination of the drilling, boring, and reaming tables (including the drilling, boring, and reaming constants) and is to be used on the average line of work, except bushings.

Table VIII is a threading chart for the different groups of materials and is based on the speeds and number of cuts shown in Table XIII. The depth of thread has been calculated on a 30-degree angle. The time values include time for engaging and releasing half nut, 3-inch return carriage travel for every cut, and gaging time. The threading standards are divided into four different classes, namely, 1, 2, 3, and 4. The standard drawing for threading, No. 74014, shows that Class 1 and 4 threads have standard tolerances, whereas Class 2 and 3 must be held accurate; therefore, three additional cuts and additional gaging time have been allowed for Class 2 and 3 thread.

The time values in this table have been derived from the following equation:

$$\text{Total cutting time} = (\text{length of cut}) \times \frac{0.0167}{\dfrac{\text{Cutting speeds}}{\text{diameter} \times \frac{\pi}{12}} \times \dfrac{1}{\text{No. of threads}}} \times$$

(*f*) No. of cuts.

$$\text{Number of cuts per thread} = \frac{\text{depth of one side of thread}}{\text{feed per cut in inches}}.$$

The constant when multiplied by the diameter and length of thread plus the threading constant will give the total time required for threading.

Use of Tables:

Every operation is to be classified on its own individual merits. Do not classify the whole job but weigh each operation separately.

On facing where the length of cut exceeds 1 inch, subtract 50 per cent of the length of cut from the outside diameter and use as a cutting diameter, excepting diameters less than the minimum which is shown on Table III.

Due to the high cutting speeds which can be used to machine brass and bronze, it is obvious that on the smaller diameters the cutting speed cannot be obtained. The minimum diameter to be used for each respective group of material is shown on Tables III, IV, and VIII.

When applying Table III, $\frac{1}{8}$ inch is to be added to the actual length of cuts to allow for irregularities in castings and sticks. When applying Table IV, $\frac{1}{16}$ inch is to be added to the actual depth of the groove. When applying Table V, VI, or VII, the actual depth of the hole is taken. When applying Table VIII, the actual length of the thread is taken.

Extreme care must be taken when applying the following tables. Table V is for drilling only; Table VI is for reaming only; and Table VII is for drilling, boring, and reaming combined.

On angular faces, taper bores, and taper turns, 50 per cent should be added to the allowed time.

Application:

This formula applies to all machining done on the engine lathes and Fox lathes under conditions existing at the present time, except when the number of pieces exceeds the maximum normal activity, which is about six.

Analysis:

Tools and equipment needed are Armstrong tool holders, forged cutting tools, drills, center drills, reamers, taps, gages, scales, micrometers, scrapers, files, calipers, square, screwdriver, hammer, socket and open end wrenches, dogs, special tools, counterbores, face plates, angle plates, chucks, chisels, bench brush, oil stones, and oil cans.

Jobs are delivered to and removed from the lathe work-ready space by laborers under the supervision of the production department.

The group leader assists the operator in making the set-up and sees that the work, tickets, and drawings are available. He also plans the work as is most efficient and practical.

To cover fatigue and unavoidable and personal delays, a general allowance has been made of 15 per cent on all part handling time and 10 per cent for cutting time.

To care for time spent in cleaning and oiling machines, an allowance of 2 per cent should be added to the each-piece and set-up values where the group system is operative. When work is done on the individual basis, the cleaning and oiling time should be taken care of by a separate time ticket.

Study drawing per operation covers studying each finished dimension shown on the drawing to determine size, finish, and accuracy required. Since it has been found that the average job requires four dimensions to be checked to start the job, the value for this operation is allowed four times in the set-up constant.

Time for stamping the order, drawing, and piece number on the job has been allowed once in the set-up constant for an average of 12 letters per job. When more than one piece is on the order, the stamping is done while machine is making the cut.

Cuttings are removed from the machine by laborers.

Time for tapping will be obtained from floor by time study.

In the each-piece constant, 30 inches of carriage travel and 20 inches of tail-stock travel have been allowed. This is representative of the average amount of travel on every job except on threading jobs where the travel is taken care of in the elemental constant.

An actual check on a number of threading jobs shows that the average thread is 2 inches long. Therefore, 3 inches of carriage travel per cut has been allowed on all threading jobs, this travel allowing for the average length of thread plus ½-inch tool clearance on each end.

Set calipers has been allowed twice in the set-up constant for each job; when calipers must be set more than twice, it can be done while machine is making cut.

The value for put in and remove forged tool or tool holder has been allowed once in the set-up for every tool used. Since bit tools are used in the majority of cases, the value for "Place bit tool in and remove from holder" has been allowed in the constant per operation.

The operation "Screw out draw-chuck nut to remove part" occurs on about 50 per cent of the draw-chuck work. Therefore, the constant for this operation is divided by 2 and is allowed on every piece where the draw-chuck is used.

Time has been allowed in the set-up constant to check the first casting. Additional pieces are checked while the machine is making cut.

Studies over a variety of work show that a certain amount of time is lost on the first piece. This time varies with the complexity of the job. An average value of 0.15 hour determined by time study on various jobs has been added to the set-up constant to take care of this condition.

Fifty per cent of the time allowance for "Adjust steady rest" is allowed in the each-piece value under "Number of times steady rest is moved" to compensate for the occasional adjustments made when steady rest is moved from one position to another.

Time studies used for the construction of this formula were taken on the present line of work. This work, due to the small number of pieces, does

not allow for any extensive preparation. On a small number of pieces, there is a slight hesitation between operations depending on the skill of the operator, while on active work the operator will work automatically with a minimum of lost motion. It is then obvious from the foregoing that this formula will not apply to the occasional active job. Therefore, in order to establish a true time value on active work, a time study or floor check will be necessary.

Procedure:

Get job, get tools, place in chuck, tighten and true, start machine, set tools, machine part, tighten or loosen tools where necessary, lock and unlock carriage where necessary, engage and release feed where necessary, stop machine, gage, release chuck jaws, remove piece, and lay aside.

TIME STUDIES

Study	Number	Date	Taken by
S-1	1	5–9–29	A. H. M.
S-2	1	5–8–29	"
S-3	2	5–2–29	"
S-4	2	4–29–29	"
S-5	1	5–1–29	"
S-6	1	5–3–29	"
S-7	1	5–2–29	"
S-8	1	4–26–29	"
S-9	1	4–29–29	"
S-10	1	4–30–29	"
S-11	1	5–13–29	"
S-12	3	4–30–29	"
S-13	2	5–1–29	"
S-14	3	5–17–29	"
S-15	1	5–20–29	"
S-16	4	5–17–29	"
S-17	1	5–21–29	"
S-18	2	5–17–29	"
S-19	1	5–27–29	"
S-20	3	5–24–29	"

TABLE OF DETAIL OPERATIONS

Symbol	Operation Description	Time Allowed	Reference
A	Pick up part and move to machine.......	0.0049	*S*-3
B	Place medium part in chuck.............	0.0022	*S*-1
C	Tighten independent chuck 18-inch lathe.	0.0104	*S*-6
D	Tighten chuck with pipe on wrench.......	0.0033	*S*-1
E	True up part on chuck..................	0.0318	*S*-1
F	Pick up aligning bar from floor...........	0.0015	*S*-6
G	Pick up surface gage....................	0.0010	*S*-1
H	Align part in halves (with surface gage)..	0.0383	*S*-4
I	Remove aligning bar to floor............	0.0013	*S*-8
J	Lay aside surface gage..................	0.0013	*S*-1

TABLE OF DETAIL OPERATIONS.—(*Continued*)

Symbol	Operation Description	Time Allowed	Reference
K	Move carriage forward (per inch)	0.00036	*S*-1-9
L	Pick up tool post	0.0010	*S*-1
M	Place tool post in compound	0.0019	*S*-3
N	Tighten tool in tool post	0.0046	*S*-1
O	Set and tighten tool bit in tool holder	0.0036	*S*-1
P	Start machine	0.0008	*S*-1-4-6-7-9-13
Q	Set to cut	0.0021	*S*-6
R	Engage feed	0.0005	*S*-1-5-6-7-8-9-13
S	Release feed	0.00045	*S*-4-6
T	Stop machine	0.0010	*S*-4-6-7-13
U	Try for size (calipers)	0.0045	*S*-6
V	Try for size (scale)	0.0051	*S*-8
W	Return carriage (per inch)	0.00034	*S*-3
X	Get tool from cupboard (except cutting tool)	0.0073	*S*-12
Y	Remove tool bit	0.0028	*S*-1
Z	Grind tool	0.0158	*S*-3
A-1	Try for size (micrometer)	0.0051	*S*-3
B-1	Lock carriage	0.0016	*S*-2
C-1	Wait for crane	0.0120	*S*-14
D-1	Square out corner	0.0068	*S*-1
E-1	File smooth or burr with scraper	0.0060	*S*-1-11
F-1	Pick up large boring bar	0.0019	*S*-3
G-1	Set large boring bar in compound	0.0037	*S*-1
H-1	Tighten large boring bar	0.0161	*S*-8
I-1	Set inside micrometers	0.0105	*S*-13
J-1	Remove part from floor to chuck, or *vice versa* (with crane)	0.0164	*S*-14
K-1	Set scale and stop for measuring	0.0109	*S*-1
L-1	Unlock carriage	0.0012	*S*-1
M-1	Loosen compound	0.0027	*S*-2
N-1	Set compound to angle	0.0062	*S*-2
O-1	Tighten compound	0.0023	*S*-2
P-1	Set compound straight	0.0024	*S*-1
Q-1	Study drawing (per operation)	0.0055	*S*-12
R-1	Set cross-feed dial to depth	0.0078	Average
S-1	Try for size (plug or pin gage)	0.0035	*S*-8
T-1	Change speed	0.0020	*S*-11
U-1	Radius $\frac{1}{8}$ inch	0.0095	*S*-1
V-1	Remove steady rest 24-inch E. lathe (with crane)	0.0168	*S*-14
W-1	Pick up scraper or file	0.0009	*S*-3
X-1	Loosen independent chuck 18-inch lathe	0.0065	Average
Y-1	Tie tag on job	0.0031	*H*-11 No. 6
Z-1	Set jaws to diameter of work	0.0220	Average
A-2	Pick up small part	0.0011	*S*-5-7

TABLE OF DETAIL OPERATIONS.—(*Continued*)

Symbol	Operation Description	Time Allowed	Reference
B-2	Place small part in draw chuck	0.0009	*S*-10
C-2	Tap part in draw chuck	0.0010	*S*-2
D-2	Tighten draw chuck	0.0011	*S*-2
E-2	Loosen draw chuck	0.0011	*S*-2-10
F-2	Screw draw chuck out to remove part (average every two jobs)	0.0022	*S*-2
G-2	Lay small part aside	0.0010	*S*-9
H-2	Lay file, scraper, or wrench aside	0.0005	*S*-2
I-2	Remove tag and place on cupboard	0.0054	*S*-4
J-2	Loosen boring bar (per nut)	0.0038	*S*-3
K-2	Remove boring bar to floor	0.0032	*S*-4
L-2	Set threading tool	0.0138	*S*-11
M-2	Set stop for threading	0.0028	*S*-3
N-2	Chamfer $\frac{1}{8}$ inch	0.0034	Average
O-2	Engage half nut	0.0007	*S*-3
P-2	Release half nut	0.0004	*S*-3
Q-2	Measure with thread gage	0.0220	Average
R-2	Blow chips from thread	0.0023	*S*-11
S-2	Remove chuck 18-inch lathe	0.0106	*S*-3
T-2	Get threaded jig from bin	0.0309	*S*-3
U-2	Screw threaded jig on spindle	0.0089	*S*-3
V-2	Pick up medium part from floor	0.0013	*S*-3
W-2	Screw medium part on threaded jig	0.0078	*S*-3
X-2	Change feed	0.0016	*S*-3
Y-2	Push tail stock forward (per inch)	0.00015	*S*-9
Z-2	Tighten tail stock (per nut)	0.0013	*S*-3
A-3	Pick up strap wrench	0.0012	*S*-3
B-3	Loosen part from threaded jig	0.0104	*S*-3
C-3	Remove medium part from threaded jig	0.0048	*S*-3
D-3	Remove medium part to floor	0.0017	*S*-3
E-3	Remove threaded jig from spindle	0.0091	*S*-3
F-3	Pick up ring clamp from floor	0.0045	*S*-4
G-3	Tighten ring clamp on work	0.0204	*S*-4
H-3	Get cutting tool from cupboard	0.0081	*S*-4
I-3	Look for and get pipe center	0.0348	*S*-4
J-3	Remove tool post from compound	0.0043	*S*-4
K-3	Stamp (per letter)	0.0022	*S*-4
L-3	Tap part on plug with hammer	0.0014	*S*-5
M-3	Pull tail stock back (per inch)	0.00015	*S*-5
N-3	Tap part on plug with hammer, to loosen	0.0041	*S*-5
O-3	Tap part against stops with hammer	0.0037	*S*-7
P-3	Chuck and true up long part 24-inch lathe	0.1978	*S*-8
Q-3	Set calipers to scale	0.0063	*S*-11
R-3	Adjust steady rest	0.0125	*S*-8
S-3	Apply white lead on steady-rest spot	0.0013	*S*-8
T-3	Stone tool or tool bit	0.0059	*S*-8

TABLE OF DETAIL OPERATIONS.—(*Continued*)

Symbol	Operation Description	Time Allowed	Reference
U-3	Place sleeve on tail-stock tool	0.0020	*H*-11 No. 6
V-3	Place tool or center in tail stock	0.0017	*S*-8
W-3	Remove tool or center from tail stock	0.0025	*S*-11
X-3	Remove sleeve from tail-stock tool	0.0034	*S*-8
Y-3	Lock taper attachment	0.0086	*S*-8
Z-3	Set boring bar central with surface gage	0.0169	*S*-8
A-4	Unlock taper attachment	0.0109	*S*-8
B-4	Get stick and emery cloth	0.0028	*S*-8
C-4	Polish (per inch)	0.0083	*S*-8
D-4	Place emery cloth on stick	0.0094	*S*-8
E-4	Loosen chuck 24-inch lathe	0.0098	*S*-8
F-4	Change chuck for face plate, or *vice versa*, 24-inch E. lathe	0.0447	*S*-8
G-4	Get jig for diffusers	0.0129	*S*-8
H-4	File burrs off face plate	0.0291	*S*-8
I-4	Set jig in place on face plate	0.0054	*S*-8
J-4	Tighten jig to face plate (per bolt)	0.0079	*S*-8
K-4	Set large part in jig	0.0208	*S*-8
L-4	Tighten nuts in jig (per nut)	0.0052	*S*-8
M-4	True up part in universal chuck	0.0041	*H*-11 No. 6
N-4	Make straight plug for bushings	0.1521	*S*-17
O-4	Set taper attachment	0.0497	*S*-8
P-4	Open steady rest	0.0042	*S*-8
Q-4	Loosen and remove nuts in jig (per nut)	0.0029	*S*-8
R-4	Loosen clamp in jig and lay aside (per clamp)	0.0030	*S*-8
S-4	Remove large part from jig	0.0013	*S*-8
T-4	Lay aside large part	0.0058	*S*-8
U-4	Set small part in jig and tap with hammer	0.0039	*S*-9
V-4	Tighten set screw in jig (per screw)	0.0016	*S*-9
W-4	Remove tool from tool post	0.0038	*S*-9
X-4	Loosen set screws in jigs (per screw)	0.0017	*S*-9
Y-4	Remove small part from jig	0.0007	*S*-9
Z-4	Clean chips from draw chuck	0.0007	*S*-10
A-5	Place small part in universal chuck	0.0017	*S*-11
B-5	Tighten universal chuck	0.0029	*S*-11
C-5	Remove small part from draw chuck	0.0005	*S*-10
D-5	Set to chase	0.0030	*S*-3
E-5	Pick up thread gage	0.0010	*S*-11
F-5	Loosen and remove small part from universal chuck	0.0024	*S*-11
G-5	Make small threaded plug	0.2494	*S*-11
H-5	Screw small part on threaded plug	0.0046	*S*-11
I-5	Pick up pipe wrench	0.0010	*S*-11
J-5	Loosen small part on threaded plug	0.0017	*S*-11
K-5	Remove small part from threaded plug	0.0014	*S*-11

TABLE OF DETAIL OPERATIONS.—(*Continued*)

Symbol	Operation Description	Time Allowed	Reference
L-5	Get large angle plate from floor (helper)	0.0053	*S*-12
M-5	Wipe face plate	0.0049	*S*-12
N-5	Get packing from cupboard (per bolt)	0.0058	*S*-12
O-5	Get clamps and bolts from cupboard (per bolt)	0.0200	*S*-12
P-5	Set and tighten clamps (per bolt)	0.0264	*S*-12
Q-5	Get block for balancing	0.0051	*S*-12
R-5	Set and tighten balance block	0.0534	*S*-12
S-5	Remove excess packing to cupboard (per bolt)	0.0019	*S*-12
T-5	Set and tighten angle plate	0.0765	*S*-12
U-5	Try for balance	0.0044	*S*-12
V-5	Chalk small valve stem (for straightening)	0.0187	*S*-13
W-5	Tap part with hammer (to straighten)	0.0100	*S*-13
X-5	Try valve cage	0.0551	*S*-13
Y-5	Try paper on seats	0.0121	*S*-13
Z-5	Walk to time office	0.0059	*S*-15
A-6	Wait for service at time office	0.0042	Average
B-6	Get time ticket	0.0053	*S*-15
C-6	Get blue print	0.0144	Average
D-6	Walk back to machine from time office	0.0053	*S*-15
E-6	Walk to tool crib from time office	0.0183	Average
F-6	Wait for service at tool crib	0.0132	Average
G-6	Turn old tools in and get new tools out (per tool)	0.0077	Average
H-6	Walk back to machine from tool crib	0.0261	Average
I-6	Set threading tool to work	0.0007	*S*-19
J-6	Take off ring clamp	0.0104	*H*-11 No. 6
K-6	Measure part with taper gage	0.0222	*H*-11 No. 6
L-6	Tighten independent chuck 24-inch lathe	0.0299	*H*-11 No. 6
M-6	Remove medium part from independent chuck	0.0027	*S*-16
N-6	Pick up or lay aside tools at crib (per tool)	0.0008	*H*-11 No. 2
O-6	Lay aside tools at machine (per tool)	0.0019	*H*-11 No. 2
P-6	Pick up tools to be returned (per tool)	0.0018	*H*-11 No. 2
Q-6	Place tools in locker (per tool)	0.0017	*H*-11 No. 2
R-6	Grind threading tool	0.1070	*H*-11 No. 6
S-6	Close steady rest	0.0036	*H*-11 No. 6
T-6	Set steady rest on ways or floor 18-inch lathe	0.0116	*H*-11 No. 6
U-6	Loosen steady rest (one nut)	0.0024	*H*-11 No. 6
V-6	Set steady rest to spot	0.0036	*H*-11 No. 6
W-6	Tighten steady rest (one nut)	0.0037	*H*-11 No. 6
X-6	Use stop clamps	0.0770	*H*-11 No. 2
Y-6	Center	0.0056	*S*-20
Z-6	Loosen tail-stock nuts (per nut)	0.0015	*S*-20
A-7	Lubricate hole for reaming	0.0031	*S*-20

Synthesis:

Set-up Time.—N-6 + O-6 + P-6 + G-6 = 0.0008 + 0.0019 + 0.0018 + 0.0077 = 0.0122 = constant for get and return tools to tool crib.

H-3 + Z + T-3 + N + W-4 + Q-6 = 0.0081 + 0.0158 + 0.0059 + 0.0046 + 0.0038 + 0.0017 = 0.0399 = constant for number of forged tools or tool holders used (except threading).

Q-6 + H-3 + R-6 + T-3 + R-1 + L-2 + D-5 + M-2 = 0.0017 + 0.0081 + 0.1070 + 0.0059 + 0.0078 + 0.0138 + 0.0030 + 0.0028 = 0.1501 = constant for number of threading tools used.

4Q-1 + 3X + Z-5 + A-6 + B-6 + C-6 + D-6 + A + Z-1 + 12K-3 + Y-1 + 2Q-3 + V-3 + W-3 + E-6 + F-6 + H-6 + I-2 = 0.0220 + 0.0219 + 0.0059 + 0.0042 + 0.0053 + 0.0144 + 0.0053 + 0.0049 + 0.0220 + 0.0264 + 0.0031 + 0.0126 + 0.0017 + 0.0025 + 0.0183 + 0.0132 + 0.0261 + 0.0054 + 0.15 = 0.365 = constant for chuck or chuck and center job.

2S-3 + 2V-1 + 2C-1 + R-3 + U-6 + W-6 = 0.0026 + 0.0336 + 0.0240 + 0.0125 + 0.0024 + 0.0036 + 0.0037 = 0.0824 = constant when steady rest is used, 24-inch lathe.

2S-3 + 2T-6 + R-3 + U-6 + V-6 + W-6 = 0.0026 + 0.0232 + 0.0125 + 0.0024 + 0.0036 + 0.0037 = 0.0480 = constant when steady rest is used, 18-inch lathe.

2M-1 + N-1 + 2O-1 + P-1 = 0.0054 + 0.0062 + 0.0046 + 0.0024 = 0.0186 = constant for number of times compound is turned to angle.

Each-piece Time.—P + T + 15K + 15W + 10Y-2 + 10M-3 = 0.0008 + 0.0010 + 0.0054 + 0.0051 + 0.0015 + 0.0015 = 0.0153 = each-piece constant.

F + G + H + I + J = 0.0015 + 0.0010 + 0.0383 + 0.0013 + 0.0013 = 0.0434 = constant for align part in halves.

B-2 + C-2 + D-2 + E-2 + $\frac{F\text{-}2}{2}$ + Z-4 = 0.0009 + 0.0010 + 0.0011 + 0.0011 + 0.0011 + 0.0007 = 0.0059 = constant when draw chuck is used.

2P + 2T + A-5 + B-5 + F-5 = 0.0016 + 0.0020 + 0.0017 + 0.0029 + 0.0024 = 0.0106 = constant when universal chuck is used.

3P + 3T + C + D + E + X-1 = 0.0024 + 0.0030 + 0.0104 + 0.0033 + 0.0318 + 0.0065 = 0.0574 = constant when independent chuck is used, 18-inch lathe.

3P + 3T + L-6 + E + E-4 = 0.0024 + 0.0030 + 0.0299 + 0.0318 + 0.0098 = 0.0769 = constant when independent chuck is used, 24-inch lathe.

H-5 + I-5 + J-5 + K-5 + H-2 = 0.0046 + 0.0010 + 0.0017 + 0.0014 + 0.0005 = 0.0092 = constant for put on and remove small part on threaded jig.

W-2 + A-3 + B-3 + C-3 + H-2 = 0.0078 + 0.0012 + 0.0104 + 0.0048 + 0.0005 = 0.0247 = constant for put on and remove medium part on threaded jig.

L + M + J-3 + F-1 + G-1 + H-1 + 2J-2 + K-2 + 2Y + 2O + Z-3 = 0.0010 + 0.0019 + 0.0043 + 0.0019 + 0.0037 + 0.0161 + 0.0076 + 0.0032 + 0.0056 + 0.0072 + 0.0167 = 0.0694 = constant for number of times large boring bar is used in compound.

A-0 I-6 + O-2 + P-2 = 0.0007 + 0.0007 + 0.0004 = 0.0018 = constant for number of times half nut is engaged and released.

B-0 B-1 + L-1 = 0.0016 + 0.0012 = 0.0028 = constant for number of times carriage is locked and unlocked.

C-0 R + S = 0.0005 + 0.00045 = 0.00095 = constant for number of times feed is engaged and released.

D-0 P + T + U = 0.0008 + 0.0010 + 0.0045 = 0.0063 = constant for calipers.

E-0 P + T + A-1 = 0.0008 + 0.0010 + 0.0051 = 0.0069 = constant for micrometers.

F-0 P + T + V = 0.0008 + 0.0010 + 0.0051 = 0.0069 = constant for scale.

G-0 P + T + S-1 = 0.0008 + 0.0010 + 0.0035 = 0.0053 = constant for plug or pin gage.

P + T + Q-2 = 0.0008 + 0.0010 + 0.0220 = 0.0238 = constant for thread gage.

P + T + K-6 = 0.0008 + 0.0010 + 0.0222 = 0.0240 = constant for taper gage.

A-2 + B-2 + C-5 + C-2 = 0.0011 + 0.0009 + 0.0005 + 0.0010 = 0.0035 = constant for handle small part.

B + M-6 + V-2 + D-3 = 0.0022 + 0.0027 + 0.0013 + 0.0017 = 0.0079 = constant for handle medium part.

2C-1 + 2J-1 = 0.0240 + 0.0328 = 0.0568 = constant for handle crane part.

H-0 O + Y = 0.0036 + 0.0028 = 0.0064 = constant for set and remove tool bit in tool holder.

P-4 + S-6 = 0.0042 + 0.0036 = 0.0078 = constant for number of times steady rest is opened and closed.

$U\text{-}6 + W\text{-}6 + V\text{-}6 + \frac{R\text{-}3}{6} + 2S\text{-}3$ = 0.0024 + 0.0036 + 0.0037 + 0.0062 + 0.0026 = 0.0185 = constant for number of times steady rest is moved.

L-3 + N-3 = 0.0014 + 0.0041 = 0.0055 = constant when small part is put on plug.

F-3 + G-3 + J-6 = 0.0045 + 0.0204 + 0.0104 = 0.0353 = constant when ring clamp is used.

W-1 + E-1 + H-2 = 0.0009 + 0.0060 + 0.0005 = 0.0074 = constant for file smooth or burr with scraper (per job).

Y-3 + O-4 + A-4 = 0.0086 + 0.0497 + 0.0109 = 0.0692 = constant for set taper attachment.

T-2 + U-2 + E-3 = 0.0309 + 0.0089 + 0.0091 = 0.0489 = constant when threaded jig is used on spindle.

2L-5 + M-5 + 2N-5 + 2O-5 + 2P-5 + Q-5 + R-5 + 2S-5 + T-5 + U-5 = 0.0106 + 0.0049 + 0.0116 + 0.0400 + 0.0528 + 0.0051 + 0.0534 + 0.0038 + 0.0765 + 0.0044 = 0.2631 = constant when large angle plate is used.

V-5 + W-5 = 0.0187 + 0.0100 = 0.0287 = constant for straighten valve stem.

3P + 3T + X-5 + Y-5 + 30M-3 + 30Y-2 = 0.0024 + 0.0030 + 0.0551 + 0.0121 + 0.0045 + 0.0045 = 0.0816 = constant for fit valve to cage.

$\frac{B\text{-}4}{10} + C\text{-}4 + \frac{D\text{-}4}{10}$ − 0.00028 + 0.0083 + 0.00094 = 0.0095 = constant for polish per inch.

$C + D + C\text{-}3$ = 0.0104 + 0.0033 + 0.0037 = 0.0174 = constant for tighten chuck 16- or 18-lathe and tap part against stop clamps, where part does not require truing up.

$C\text{-}1 + F\text{-}4$ = 0.0120 + 0.0447 = 0.0567 = constant for change chuck for face plate, or *vice versa*, 24-inch lathe.

$G\text{-}4 + H\text{-}4 + I\text{-}4 + 4J\text{-}4$ = 0.0129 + 0.0291 + 0.0054 + 0.0316 = 0.0790 = constant when using jig for diffusers.

$K\text{-}4 + 4L\text{-}4 + 2Q\text{-}4 + 2R\text{-}4 + S\text{-}4 + T\text{-}4$ = 0.0208 + 0.0208 + 0.0058 + 0.0060 + 0.0013 + 0.0058 = 0.0607 = constant for clamp and remove part from diffuser jig.

$U\text{-}4 + 3V\text{-}4 + 3X\text{-}4 + Y\text{-}4$ = 0.0039 + 0.0048 + 0.0051 + 0.0007 = 0.0145 = constant for place and remove small part in jig.

(f) = number of cuts × $(A\text{-}0 + 3W) + E\text{-}5 + R\text{-}2 + (G\text{-}0)$ = constant for threading, Class 1 and 4.

(f) = number of cuts × $(A\text{-}0 + 3W) + E\text{-}5 + R\text{-}2 + 2(G\text{-}0)$ = constant for threading Class 2 and 3.

Speed, Feed, Tool, and Gage Constant for Boring or Turning:

Strong: $2(C\text{-}0) + T\text{-}1 + X\text{-}2 + (H\text{-}0) + 2Q + (D\text{-}0)$ = 0.0019 + 0.0020 + 0.0016 + 0.0064 + 0.0042 + 0.0063 = 0.0224 = constant for rough finish.

$3(C\text{-}0) + 2T\text{-}1 + 2X\text{-}2 + 2(H\text{-}0) + 3Q + (D\text{-}0) + (E\text{-}0)$ = 0.0027 + 0.0040 + 0.0032 + 0.0128 + 0.0063 + 0.0063 + 0.0069 = 0.0422 = constant for regular finish.

$4(C\text{-}0) + 2T\text{-}1 + 2X\text{-}2 + 2(H\text{-}0) + 4Q + (D\text{-}0) + 2(E\text{-}0)$ = 0.0038 + 0.0040 + 0.0032 + 0.0128 + 0.0084 + 0.0063 + 0.0138 = 0.0523 = constant for accurate finish.

Medium: $3(C\text{-}0) + T\text{-}1 + X\text{-}2 + (H\text{-}0) + 3Q + (D\text{-}0)$ = 0.0027 + 0.0020 + 0.0016 + 0.0064 + 0.0063 + 0.0063 = 0.0253 = constant for rough finish.

$4(C\text{-}0) + 2T\text{-}1 + 2X\text{-}2 + 2(H\text{-}0) + 4Q + (D\text{-}0) + (E\text{-}0)$ = 0.0038 + 0.0040 + 0.0032 + 0.0128 + 0.0084 + 0.0063 + 0.0069 = 0.0454 = constant for regular finish.

$5(C\text{-}0) + 2T\text{-}1 + 2X\text{-}2 + 2(H\text{-}0) + 5Q + (D\text{-}0) + 2(E\text{-}0)$ = 0.0047 + 0.0040 + 0.0032 + 0.0128 + 0.0105 + 0.0063 + 0.0138 = 0.0553 = constant for accurate finish.

Weak: $4(C\text{-}0) + T\text{-}1 + X\text{-}2 + (H\text{-}0) + 4Q + 2(D\text{-}0)$ = 0.0038 + 0.0020 + 0.0016 + 0.0064 + 0.0084 + 0.0126 = 0.0348 = constant for rough finish.

$5(C\text{-}0) + 2T\text{-}1 + 2X\text{-}2 + 2(H\text{-}0) + 5Q + 2(D\text{-}0) + 2(E\text{-}0)$ = 0.0047 + 0.0040 + 0.0032 + 0.0128 + 0.0105 + 0.0126 + 0.0138 = 0.0616 = constant for regular finish.

$6(C\text{-}0) + 2T\text{-}1 + 2X\text{-}2 + 2(H\text{-}0) + 6Q + 2(D\text{-}0) + 3(E\text{-}0)$ = 0.0057 + 0.0040 + 0.0032 + 0.0128 + 0.0126 + 0.0126 + 0.0207 = 0.0716 = constant for accurate finish.

Speed, Feed, Tool, and Gage Constant for Facing:

Strong: $2(C\text{-}0) + T\text{-}1 + X\text{-}2 + (H\text{-}0) + 2Q + (F\text{-}0) + (B\text{-}0) = 0.0019 + 0.0020 + 0.0016 + 0.0064 + 0.0042 + 0.0069 + 0.0028 = 0.0258 =$ constant for rough finish.

$3(C\text{-}0) + 2T\text{-}1 + 2X\text{-}2 + 2(H\text{-}0) + 3Q + 2(F\text{-}0) + (B\text{-}0) = 0.0027 + 0.0040 + 0.0032 + 0.0128 + 0.0063 + 0.0138 + 0.0028 = 0.0456 =$ constant for regular finish.

$4(C\text{-}0) + 2T\text{-}1 + 2X\text{-}2 + 2(H\text{-}0) + 4Q + 2(F\text{-}0) + (E\text{-}0) + (B\text{-}0) = 0.0038 + 0.0040 + 0.0032 + 0.0128 + 0.0084 + 0.0138 + 0.0069 + 0.0028 = 0.0557 =$ constant for accurate finish.

Medium: $3(C\text{-}0) + T\text{-}1 + X\text{-}2 + (H\text{-}0) + 3Q + (B\text{-}0) + 2(F\text{-}0) = 0.0027 + 0.0020 + 0.0016 + 0.0064 + 0.0063 + 0.0028 + 0.0138 = 0.0356 =$ constant for rough finish.

$4(C\text{-}0) + 2T\text{-}1 + 2X\text{-}2 + 2(H\text{-}0) + 4Q + (B\text{-}0) + 3(F\text{-}0) = 0.0038 + 0.0040 + 0.0032 + 0.0128 + 0.0084 + 0.0028 + 0.0207 = 0.0557 =$ constant for regular finish.

$5(C\text{-}0) + 2T\text{-}1 + 2X\text{-}2 + 2(H\text{-}0) + 5Q + (B\text{-}0) + 3(F\text{-}0) + (E\text{-}0) = 0.0047 + 0.0040 + 0.0032 + 0.0128 + 0.0105 + 0.0028 + 0.0207 + 0.0069 = 0.0656 =$ constant for accurate finish.

Weak: $4(C\text{-}0) + T\text{-}1 + X\text{-}2 + (H\text{-}0) + 4Q + (B\text{-}0) + 3(F\text{-}0) = 0.0038 + 0.0020 + 0.0016 + 0.0064 + 0.0084 + 0.0028 + 0.0287 = 0.0457 =$ constant for rough finish.

$5(C\text{-}0) + 2T\text{-}1 + 2X\text{-}2 + 2(H\text{-}0) + 5Q + (B\text{-}0) + 4(F\text{-}0) = 0.0047 + 0.0040 + 0.0032 + 0.0128 + 0.0105 + 0.0028 + 0.0276 = 0.0656 =$ constant for regular finish.

$6(C\text{-}0) + 2T\text{-}1 + 2X\text{-}2 + 2(H\text{-}0) + 6Q + (B\text{-}0) + 4(F\text{-}0) + (E\text{-}0) = 0.0057 + 0.0040 + 0.0032 + 0.0128 + 0.0126 + 0.0028 + 0.0276 + 0.0069 = 0.0756 =$ constant for accurate finish.

Speed, Feed, Tool, and Gage Constant for Grooving:

$(C\text{-}0) + (B\text{-}0) + T\text{-}1 + X\text{-}2 + (H\text{-}0) + Q + (F\text{-}0) = 0.0010 + 0.0028 + 0.0020 + 0.0016 + 0.0064 + 0.0021 + 0.0069 = 0.0228 =$ constant for $\frac{1}{4}$-inch groove above ± 0.003 inch.

$2(C\text{-}0) + (B\text{-}0) + T\text{-}1 + X\text{-}2 + 2(H\text{-}0) + 2Q + (F\text{-}0) + (G\text{-}0) = 0.0019 + 0.0028 + 0.0020 + 0.0016 + 0.0128 + 0.0042 + 0.0069 + 0.0053 = 0.0375 =$ constant for $\frac{1}{4}$-inch groove ± 0.000 inch.

$2(C\text{-}0) + (B\text{-}0) + T\text{-}1 + X\text{-}2 + 2(H\text{-}0) + 2Q + (F\text{-}0) = 0.0019 + 0.0028 + 0.0020 + 0.0016 + 0.0128 + 0.0042 + 0.0069 = 0.0322 =$ constant for $\frac{1}{2}$-inch groove above ± 0.003 inch.

$3(C\text{-}0) + (B\text{-}0) + T\text{-}1 + X\text{-}2 + 2(H\text{-}0) + 3Q + (F\text{-}0) + (G\text{-}0) = 0.0027 + 0.0028 + 0.0020 + 0.0016 + 0.0128 + 0.0063 + 0.0069 + 0.0053 = 0.0404 =$ constant for $\frac{1}{2}$-inch groove ± 0.000 inch.

$3(C\text{-}0) + (B\text{-}0) + T\text{-}1 + X\text{-}2 + 2(H\text{-}0) + 3Q + 2(F\text{-}0) = 0.0027 + 0.0028 + 0.0020 + 0.0016 + 0.0128 + 0.0053 + 0.0138 = 0.0420 =$ constant for $\frac{3}{4}$-inch groove above ± 0.003 inch.

$4(C\text{-}0) + (B\text{-}0) + T\text{-}1 + X\text{-}2 + 2(H\text{-}0) + 4Q + 2(F\text{-}0) + (G\text{-}0) = 0.0038 + 0.0028 + 0.0020 + 0.0016 + 0.0128 + 0.0084 + 0.0138 + 0.0053 = 0.0505 =$ constant for $\frac{3}{4}$-inch groove ± 0.000 inch.

$4(C\text{-}0) + (B\text{-}0) + T\text{-}1 + X\text{-}2 + 2(H\text{-}0) + 4Q + 2(F\text{-}0) = 0.0038 + 0.0028 + 0.0020 + 0.0016 + 0.0128 + 0.0084 + 0.0138 = 0.0452 =$ constant for 1-inch groove above ± 0.003 inch.

$5(C\text{-}0) + (B\text{-}0) + T\text{-}1 + X\text{-}2 + 2(H\text{-}0) + 5Q + 2(F\text{-}0) + (G\text{-}0) = 0.0047 + 0.0028 + 0.0020 + 0.0016 + 0.0128 + 0.0105 + 0.0138 + 0.0053 = 0.0535 =$ constant for 1-inch groove ± 0.000 inch.

Speed, Feed, Tool, and Gage Constant for Parting:

$(C\text{-}0) + (B\text{-}0) + T\text{-}1 + X\text{-}2 + (H\text{-}0) + Q + (F\text{-}0) = 0.0010 + 0.0028 + 0.0020 + 0.0016 + 0.0064 + 0.0021 + 0.0069 = 0.0228 =$ constant for parting.

Inspection:

Work is inspected for size and finish in accordance with the requirements for each job.

Payment:

Standard time group basis.

Approved:

Time-study Supervisor Time-study Department

TABLE III.—CENTER, CHUCK, OR CHUCK AND CENTER JOBS. BORING, TURNING, OR FACING

Finish	Strong			Medium			Weak			Extra-rough cut	Extra-finish cut	Minimum diameter to be used, inches	
	Rough	Fin-ished	Fin-ished	Rough	Fin-ished	Fin-ished	Rough	Fin-ished	Fin-ished				
Accuracy	Std.	±0.010 to ±0.003	±0.003 to ±0.000	Std.	±0.010 to ±0.003	±0.003 to ±0.000	Std.	±0.010 to ±0.003	±0.003 to ±0.000	......	......	16- or 18-in. engine lathe	24-in. engine lathe
Group 1	0.0013	0.0023	0.0034	0.0019	0.0030	0.0040	0.0026	0.0036	0.0047	0.0006	0.0011	3¼	4
Group 2	0.0019	0.0034	0.0048	0.0029	0.0043	0.0058	0.0038	0.0053	0.0067	0.0010	0.0014	2¼	3
Group 3	0.0026	0.0044	0.0062	0.0039	0.0059	0.0077	0.0052	0.0070	0.0088	0.0013	0.0018	1¾	2¼
Group 4	0.0039	0.0064	0.0089	0.0058	0.0083	0.0108	0.0077	0.0102	0.0127	0.0019	0.0025	1¼	1¾
Constants turning or boring	0.0224	0.0422	0.0523	0.0253	0.0454	0.0553	0.0348	0.0616	0.0716				
Facing	0.0258	0.0456	0.0557	0.0356	0.0557	0.0656	0.0457	0.0656	0.0756				

Total boring, turning, or facing time = (length of cut) × diameter × constant + tool constant.

TABLE IV

	Grooving								Parting		
Size of groove	Up to and including ¼ in.		From ¼ to and including ½ in.		From ½ to and including ¾ in.		From ¾ to and including 1 in.		....	Minimum diameter to be used, inches	
Accuracy	Std. to ±0.003	±0.003 to ±0.000	Std. to ±0.003	±0.003 to ±0.000	Std. to ±0.003	±0.003 to ±0.000	Std. to ±0.003	±0.003 to ±0.000	....	16- or 18-in. lathe	24-in. lathe
Group 1	0.0038	0.0075	0.0075	0.0113	0.0113	0.0150	0.0150	0.0188	0.0038	1¼	1½
Group 2	0.0050	0.0100	0.0100	0.0150	0.0150	0.0200	0.0200	0.0250	0.0050	⅞	1
Group 3	0.0064	0.0129	0.0129	0.0193	0.0193	0.0258	0.0258	0.0322	0.0064	¾	⅞
Group 4	0.0090	0.0180	0.0180	0.0270	0.0270	0.0360	0.0360	0.0450	0.0090	½	⅝
Grooving or parting constant	0.0228	0.0375	0.0322	0.0404	0.0420	0.0505	0.0452	0.0535	0.0228		

TABLE V.—DRILLING

Depth of hole, inches	Size of drill: 3/4 in. Group 1	3/4 in. Group 2	3/4 in. Group 3	3/4 in. Group 4	1 in. Group 1	1 in. Group 2	1 in. Group 3	1 in. Group 4	1 1/4 in. Group 1	1 1/4 in. Group 2	1 1/4 in. Group 3	1 1/4 in. Group 4	1 1/2 in. Group 1	1 1/2 in. Group 2	1 1/2 in. Group 3	1 1/2 in. Group 4
1/2	0.0293	0.0301	0.0301	0.0301	0.0298	0.0307	0.0307	0.0312	0.0302	0.0312	0.0312	0.0335	0.0307	0.0318	0.0319	0.0362
3/4	0.0308	0.0319	0.0319	0.0319	0.0313	0.0325	0.0325	0.0332	0.0317	0.0330	0.0330	0.0360	0.0322	0.0336	0.0338	0.0392
1	0.0324	0.0337	0.0337	0.0337	0.0329	0.0343	0.0343	0.0352	0.0333	0.0348	0.0348	0.0385	0.0338	0.0354	0.0357	0.0422
1 1/4	0.0339	0.0355	0.0355	0.0355	0.0344	0.0361	0.0361	0.0372	0.0348	0.0366	0.0366	0.0410	0.0353	0.0372	0.0376	0.0452
1 1/2	0.0355	0.0373	0.0373	0.0373	0.0360	0.0380	0.0380	0.0392	0.0364	0.0385	0.0385	0.0435	0.0369	0.0391	0.0394	0.0482
1 3/4	0.0370	0.0392	0.0392	0.0392	0.0375	0.0398	0.0398	0.0412	0.0379	0.0403	0.0403	0.0460	0.0384	0.0409	0.0413	0.0512
2	0.0386	0.0410	0.0410	0.0410	0.0391	0.0416	0.0416	0.0432	0.0395	0.0421	0.0421	0.0485	0.0400	0.0427	0.0432	0.0542
2 1/4	0.0401	0.0428	0.0428	0.0428	0.0406	0.0434	0.0434	0.0452	0.0410	0.0439	0.0439	0.0510	0.0415	0.0445	0.0451	0.0572
2 1/2	0.0417	0.0446	0.0446	0.0446	0.0422	0.0453	0.0453	0.0472	0.0426	0.0458	0.0458	0.0535	0.0431	0.0464	0.0469	0.0602
2 3/4	0.0432	0.0464	0.0464	0.0464	0.0437	0.0471	0.0471	0.0492	0.0441	0.0476	0.0476	0.0560	0.0446	0.0482	0.0488	0.0632
3	0.0448	0.0483	0.0483	0.0483	0.0453	0.0489	0.0489	0.0512	0.0457	0.0494	0.0494	0.0585	0.0462	0.0500	0.0507	0.0662
3 1/4	0.0463	0.0501	0.0501	0.0501	0.0468	0.0507	0.0507	0.0532	0.0472	0.0512	0.0512	0.0610	0.0477	0.0518	0.0525	0.0692
3 1/2	0.0479	0.0519	0.0519	0.0519	0.0484	0.0526	0.0526	0.0552	0.0488	0.0531	0.0531	0.0635	0.0493	0.0537	0.0544	0.0722
3 3/4	0.0494	0.0537	0.0537	0.0537	0.0499	0.0544	0.0544	0.0572	0.0503	0.0549	0.0549	0.0660	0.0508	0.0555	0.0562	0.0752
4	0.0510	0.0556	0.0556	0.0556	0.0515	0.0562	0.0562	0.0592	0.0519	0.0567	0.0567	0.0685	0.0524	0.0573	0.0581	0.0782
4 1/4	0.0525	0.0574	0.0574	0.0574	0.0530	0.0580	0.0580	0.0612	0.0534	0.0585	0.0585	0.0710	0.0539	0.0591	0.0600	0.0812
4 1/2	0.0541	0.0592	0.0592	0.0592	0.0546	0.0599	0.0599	0.0632	0.0550	0.0604	0.0604	0.0735	0.0555	0.0610	0.0619	0.0842
4 3/4	0.0556	0.0610	0.0610	0.0610	0.0561	0.0617	0.0617	0.0652	0.0565	0.0622	0.0622	0.0760	0.0570	0.0629	0.0637	0.0872
5	0.0572	0.0629	0.0629	0.0629	0.0577	0.0635	0.0635	0.0672	0.0581	0.0640	0.0640	0.0785	0.0586	0.0646	0.0656	0.0902
5 1/2	0.0603	0.0665	0.0665	0.0665	0.0608	0.0671	0.0671	0.0712	0.0612	0.0676	0.0676	0.0835	0.0617	0.0682	0.0693	0.0962
6	0.0634	0.0702	0.0702	0.0702	0.0639	0.0708	0.0708	0.0752	0.0643	0.0713	0.0713	0.0885	0.0648	0.0719	0.0731	0.1022

These time values include time for put on and remove sleeve, put tool in tail stock and remove, tail-stock travel, tighten and loosen tail stock, change speed, start and stop machine, center and lead of drill.

TABLE V.—DRILLING.—(*Continued*)

Depth of hole, inches	Size of drill											
	1¾ in.				2 in.				2¼ in.			
	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
½	0.0323	0.0323	0.0338	0.0391	0.0329	0.0336	0.0358	0.0424	0.0334	0.0354	0.0381	0.0459
¾	0.0341	0.0341	0.0360	0.0426	0.0347	0.0356	0.0383	0.0464	0.0352	0.0376	0.0409	0.0504
1	0.0359	0.0359	0.0382	0.0461	0.0365	0.0376	0.0408	0.0504	0.0370	0.0399	0.0437	0.0549
1¼	0.0377	0.0377	0.0404	0.0496	0.0383	0.0396	0.0433	0.0544	0.0388	0.0421	0.0465	0.0594
1½	0.0395	0.0395	0.0426	0.0531	0.0401	0.0416	0.0458	0.0584	0.0406	0.0444	0.0494	0.0639
1¾	0.0414	0.0414	0.0448	0.0566	0.0420	0.0436	0.0483	0.0624	0.0425	0.0466	0.0522	0.0684
2	0.0432	0.0432	0.0470	0.0601	0.0438	0.0456	0.0508	0.0664	0.0443	0.0489	0.0550	0.0729
2¼	0.0450	0.0450	0.0492	0.0636	0.0456	0.0476	0.0533	0.0704	0.0461	0.0511	0.0578	0.0774
2½	0.0468	0.0468	0.0514	0.0671	0.0474	0.0496	0.0558	0.0744	0.0479	0.0534	0.0607	0.0819
2¾	0.0486	0.0486	0.0536	0.0706	0.0492	0.0516	0.0583	0.0784	0.0497	0.0556	0.0635	0.0864
3	0.0505	0.0505	0.0558	0.0741	0.0511	0.0536	0.0608	0.0824	0.0516	0.0579	0.0663	0.0909
3¼	0.0523	0.0523	0.0580	0.0776	0.0529	0.0556	0.0633	0.0864	0.0534	0.0601	0.0691	0.0954
3½	0.0542	0.0542	0.0602	0.0811	0.0547	0.0576	0.0658	0.0904	0.0552	0.0624	0.0720	0.0999
3¾	0.0559	0.0559	0.0624	0.0846	0.0565	0.0596	0.0683	0.0944	0.0570	0.0646	0.0748	0.1044
4	0.0577	0.0577	0.0646	0.0881	0.0583	0.0616	0.0708	0.0984	0.0588	0.0669	0.0776	0.1089
4¼	0.0596	0.0596	0.0668	0.0916	0.0602	0.0636	0.0733	0.1024	0.0607	0.0691	0.0804	0.1134
4½	0.0615	0.0615	0.0690	0.0951	0.0620	0.0656	0.0758	0.1064	0.0625	0.0714	0.0833	0.1179
4¾	0.0633	0.0633	0.0712	0.0986	0.0638	0.0676	0.0783	0.1104	0.0643	0.0736	0.0861	0.1224
5	0.0650	0.0650	0.0734	0.1021	0.0656	0.0696	0.0808	0.1144	0.0661	0.0759	0.0889	0.1269
5½	0.0687	0.0687	0.0778	0.1091	0.0693	0.0736	0.0858	0.1224	0.0698	0.0804	0.0946	0.1359
6	0.0723	0.0723	0.0822	0.1161	0.0729	0.0776	0.0908	0.1304	0.0734	0.0849	0.1002	0.1449

These time values include time for put on and remove sleeve, put tool in tail stock and remove, tail-stock travel, tighten and loosen tail stock, change speed, start and stop machine, center and lead of drill.

TABLE V.—DRILLING.—(*Continued*)

Depth of hole, inches	Size of drill											
	2½ in.				2¾ in.				3 in.			
	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
½	0.0340	0.0373	0.0405	0.0498	0.0346	0.0394	0.0431	0.0539	0.0360	0.0416	0.0458	0.0584
¾	0.0358	0.0398	0.0436	0.0548	0.0364	0.0421	0.0465	0.0594	0.0380	0.0446	0.0495	0.0644
1	0.0376	0.0423	0.0467	0.0598	0.0383	0.0449	0.0500	0.0649	0.0400	0.0476	0.0533	0.0704
1¼	0.0394	0.0448	0.0499	0.0648	0.0401	0.0476	0.0534	0.0704	0.0420	0.0506	0.0570	0.0764
1½	0.0412	0.0473	0.0530	0.0698	0.0420	0.0504	0.0569	0.0759	0.0440	0.0536	0.0608	0.0824
1¾	0.0431	0.0498	0.0561	0.0748	0.0438	0.0531	0.0603	0.0814	0.0460	0.0566	0.0645	0.0884
2	0.0449	0.0523	0.0592	0.0798	0.0457	0.0559	0.0638	0.0869	0.0480	0.0596	0.0683	0.0944
2¼	0.0467	0.0548	0.0624	0.0848	0.0475	0.0586	0.0672	0.0924	0.0500	0.0626	0.0720	0.1004
2½	0.0485	0.0573	0.0655	0.0898	0.0494	0.0614	0.0707	0.0979	0.0520	0.0656	0.0758	0.1064
2¾	0.0503	0.0598	0.0686	0.0948	0.0512	0.0641	0.0741	0.1034	0.0540	0.0686	0.0795	0.1124
3	0.0522	0.0623	0.0717	0.0998	0.0531	0.0669	0.0776	0.1089	0.0560	0.0716	0.0833	0.1184
3¼	0.0540	0.0648	0.0749	0.1048	0.0549	0.0696	0.0810	0.1144	0.0580	0.0746	0.0870	0.1244
3½	0.0558	0.0673	0.0780	0.1098	0.0568	0.0724	0.0845	0.1199	0.0600	0.0776	0.0908	0.1304
3¾	0.0576	0.0698	0.0811	0.1148	0.0586	0.0751	0.0879	0.1254	0.0620	0.0806	0.0945	0.1364
4	0.0594	0.0723	0.0842	0.1198	0.0605	0.0779	0.0914	0.1309	0.0640	0.0836	0.0983	0.1424
4¼	0.0613	0.0748	0.0874	0.1248	0.0623	0.0806	0.0948	0.1364	0.0660	0.0866	0.1020	0.1484
4½	0.0631	0.0773	0.0905	0.1298	0.0642	0.0834	0.0983	0.1419	0.0680	0.0896	0.1058	0.1544
4¾	0.0649	0.0798	0.0936	0.1348	0.0660	0.0861	0.1017	0.1474	0.0700	0.0926	0.1095	0.1604
5	0.0667	0.0823	0.0967	0.1398	0.0679	0.0889	0.1052	0.1529	0.0720	0.0956	0.1133	0.1664
5½	0.0704	0.0873	0.1029	0.1498	0.0716	0.0944	0.1121	0.1639	0.0760	0.1016	0.1208	0.1784
6	0.0740	0.0923	0.1092	0.1598	0.0753	0.0999	0.1190	0.1749	0.0800	0.1076	0.1283	0.1904

These time values include time for put on and remove sleeve, put tool in tail stock and remove, tail-stock travel, tighten and loosen tail stock, change speed, start and stop machine, center and lead of drill.

Table VI.—Reaming

Depth of hole, inches	Size of reamer															
	3/4 in.				1 in.				1 1/4 in				1 1/2 in.			
	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
1/4																0.0251
1/2	0.0232	0.0233	0.0233	0.0237	0.0232	0.0233	0.0235	0.0241	0.0232	0.0235	0.0238	0.0246	0.0232	0.0237	0.0242	0.0264
3/4	0.0236	0.0238	0.0238	0.0243	0.0236	0.0238	0.0241	0.0250	0.0236	0.0240	0.0246	9.0258	0.0236	0.0243	0.0251	0.0278
1	0.0241	0.0243	0.0243	0.0250	0.0241	0.0243	0.0247	0.0259	0.0241	0.0246	0.0253	0.0269	0.0241	0.0250	0.0260	
1 1/4	0.0245	0.0248	0.0248	0.0257	0.0245	0.0248	0.0253	0.0268	0.0245	0.0252	0.0261	0.0281	0.0245	0.0257	0.0269	0.0292
1 1/2	0.0250	0.0253	0.0253	0.0264	0.0250	0.0253	0.0259	0.0277	0.0250	0.0258	0.0268	0.0292	0.0250	0.0264	0.0279	0.0306
1 3/4	0.0254	0.0258	0.0258	0.0270	0.0254	0.0258	0.0265	0.0286	0.0254	0.0263	0.0276	0.0304	0.0254	0.0270	0.0288	0.0319
2	0.0259	0.0263	0.0263	0.0277	0.0259	0.0263	0.0271	0.0295	0.0259	0.0269	0.0283	0.0315	0.0259	0.0277	0.0297	0.0333
2 1/4	0.0263	0.0268	0.0268	0.0284	0.0263	0.0268	0.0277	0.0304	0.0263	0.0275	0.0291	0.0327	0.0263	0.0284	0.0306	0.0347
2 1/2	0.0268	0.0273	0.0273	0.0291	0.0268	0.0273	0.0283	0.0313	0.0268	0.0281	0.0298	0.0338	0.0268	0.0291	0.0316	0.0361
2 3/4	0.0272	0.0278	0.0278	0.0297	0.0272	0.0278	0.0289	0.0322	0.0272	0.0286	0.0306	0.0350	0.0272	0.0297	0.0325	0.0374
3	0.0277	0.0283	0.0283	0.0304	0.0277	0.0283	0.0295	0.0331	0.0277	0.0292	0.0313	0.0361	0.0277	0.0304	0.0334	0.0388
3 1/4	0.0281	0.0288	0.0288	0.0311	0.0281	0.0288	0.0301	0.0340	0.0281	0.0298	0.0321	0.0373	0.0281	0.0311	0.0343	0.0402
3 1/2	0.0286	0.0293	0.0293	0.0318	0.0286	0.0293	0.0307	0.0349	0.0286	0.0304	0.0328	0.0384	0.0286	0.0318	0.0353	0.0416
3 3/4	0.0290	0.0298	0.0298	0.0324	0.0290	0.C298	0.0313	0.0358	0.0290	0.0309	0.0336	0.0396	0.0290	0.0324	0.0362	0.0429
4	0.0295	0.0303	0.0303	0.0331	0.0295	0.0303	0.0319	0.0367	0.0295	0.0315	0.0343	0.0407	0.0295	0.0331	0.0371	0.0443
4 1/4	0.0299	0.0308	0.0308	0.0338	0.0299	0.0308	0.0325	0.0376	0.0299	0.0321	0.0351	0.0419	0.0299	0.0338	0.0380	0.0457
4 1/2	0.0304	0.0313	0.0313	0.0345	0.0304	0.0313	0.0331	0.0385	0.0304	0.0327	0.0358	0.0430	0.0304	0.0345	0.0390	0.0471
4 3/4	0.0308	0.0318	0.0318	0.0351	0.0308	0.0318	0.0337	0.0394	0.0308	0.0332	0.0366	0.0442	0.0308	0.0351	0.0399	0.0484
5	0.0313	0.0323	0.0323	0.0358	0.0313	0.0323	0.0343	0.0403	0.0313	0.0338	0.0373	0.0453	0.0313	0.0358	0.0408	0.0498
5 1/2	0.0322	0.0333	0.0333	0.0371	0.0322	0.0333	0.0355	0.0421	0.0322	0.0350	0.0388	0.0476	0.0322	0.0371	0.0427	0.0526
6	0.0331	0.0343	0.0343	0.0385	0.0331	0.0343	0.0367	0.0439	0.0331	0.0361	0.0403	0.0499	0.0331	0.0385	0.0445	0.0553

These time values include time for put on and remove sleeve, put tool in tail stock and remove, tail-stock travel, tighten and loosen tail stock, change speed, start and stop machine, and lubricating time.

TABLE VI.—REAMING.—(*Continued*)

Depth of hole, inches	Size of reamer											
	1¾ in.				2 in.				2¼ in.			
	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
½	0.0233	0.0239	0.0245	0.0255	0.0234	0.0241	0.0247	0.0259	0.0235	0.0244	0.0251	0.0265
¾	0.0237	0.0247	0.0256	0.0271	0.0239	0.0250	0.0259	0.0277	0.0241	0.0254	0.0264	0.0286
1	0.0242	0.0255	0.0266	0.0287	0.0244	0.0259	0.0271	0.0296	0.0247	0.0264	0.0278	0.0307
1¼	0.0247	0.0263	0.0277	0.0303	0.0249	0.0268	0.0283	0.0314	0.0253	0.0274	0.0292	0.0328
1½	0.0252	0.0271	0.0288	0.0319	0.0255	0.0277	0.0295	0.0332	0.0259	0.0285	0.0306	0.0349
1¾	0.0256	0.0279	0.0299	0.0335	0.0260	0.0286	0.0308	0.0350	0.0265	0.0295	0.0319	0.0370
2	0.0261	0.0287	0.0309	0.0351	0.0265	0.0295	0.0319	0.0369	0.0271	0.0305	0.0333	0.0391
2¼	0.0266	0.0295	0.0320	0.0367	0.0270	0.0304	0.0331	0.0387	0.0277	0.0315	0.0347	0.0412
2½	0.0271	0.0303	0.0331	0.0383	0.0276	0.0313	0.0343	0.0405	0.0283	0.0326	0.0361	0.0433
2¾	0.0275	0.0311	0.0342	0.0399	0.0281	0.0322	0.0355	0.0423	0.0289	0.0336	0.0374	0.0454
3	0.0280	0.0319	0.0352	0.0415	0.0286	0.0331	0.0367	0.0442	0.0295	0.0346	0.0388	0.0475
3¼	0.0285	0.0327	0.0363	0.0431	0.0291	0.0340	0.0379	0.0460	0.0301	0.0356	0.0402	0.0496
3½	0.0290	0.0335	0.0374	0.0447	0.0297	0.0349	0.0391	0.0478	0.0307	0.0367	0.0416	0.0517
3¾	0.0294	0.0343	0.0385	0.0463	0.0302	0.0358	0.0403	0.0496	0.0313	0.0377	0.0429	0.0538
4	0.0299	0.0351	0.0395	0.0479	0.0307	0.0367	0.0415	0.0515	0.0319	0.0387	0.0443	0.0559
4¼	0.0304	0.0359	0.0406	0.0495	0.0312	0.0376	0.0427	0.0533	0.0325	0.0398	0.0457	0.0580
4½	0.0309	0.0367	0.0417	0.0511	0.0318	0.0385	0.0439	0.0551	0.0331	0.0408	0.0471	0.0601
4¾	0.0313	0.0375	0.0428	0.0527	0.0323	0.0394	0.0451	0.0569	0.0337	0.0418	0.0484	0.0622
5	0.0318	0.0383	0.0438	0.0543	0.0328	0.0403	0.0463	0.0588	0.0343	0.0428	0.0498	0.0643
5½	0.0328	0.0399	0.0460	0.0575	0.0339	0.0421	0.0487	0.0624	0.0355	0.0449	0.0526	0.0685
6	0.0337	0.0415	0.0481	0.0607	0.0349	0.0439	0.0511	0.0661	0.0367	0.0469	0.0553	0.0727

These time values include time for put on and remove sleeve, put tool in tail stock and remove, tail-stock travel, tighten and loosen tail stock, change speed, start and stop machine, and lubricating time.

TABLE VI.—REAMING.—(*Continued*)

Depth of hole, inches	Size of reamer											
	2½ in.				2¾ in.				3 in.			
	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
½	0.0237	0.0246	0.0254	0.0269	0.0238	0.0248	0.0257	0.0273	0.0239	0.0251	0.0259	0.0278
¾	0.0243	0.0258	0.0269	0.0292	0.0245	0.0260	0.0274	0.0298	0.0247	0.0264	0.0277	0.0306
1	0.0250	0.0269	0.0284	0.0315	0.0252	0.0273	0.0290	0.0323	0.0255	0.0278	0.0296	0.0333
1¼	0.0257	0.0281	0.0299	0.0338	0.0259	0.0285	0.0307	0.0348	0.0263	0.0292	0.0314	0.0361
1½	0.0264	0.0292	0.0315	0.0361	0.0267	0.0298	0.0324	0.0373	0.0271	0.0306	0.0332	0.0388
1¾	0.0270	0.0304	0.0330	0.0384	0.0274	0.0310	0.0341	0.0398	0.0279	0.0319	0.0350	0.0416
2	0.0277	0.0315	0.0345	0.0407	0.0281	0.0323	0.0357	0.0423	0.0287	0.0333	0.0369	0.0443
2¼	0.0284	0.0327	0.0360	0.0430	0.0288	0.0335	0.0374	0.0448	0.0295	0.0347	0.0387	0.0471
2½	0.0291	0.0338	0.0376	0.0453	0.0296	0.0348	0.0391	0.0473	0.0303	0.0361	0.0405	0.0498
2¾	0.0297	0.0350	0.0391	0.0476	0.0303	0.0360	0.0408	0.0498	0.0311	0.0374	0.0423	0.0526
3	0.0304	0.0361	0.0406	0.0499	0.0310	0.0373	0.0424	0.0523	0.0319	0.0388	0.0442	0.0553
3¼	0.0311	0.0373	0.0421	0.0522	0.0317	0.0385	0.0441	0.0548	0.0327	0.0402	0.0460	0.0581
3½	0.0318	0.0384	0.0437	0.0545	0.0325	0.0398	0.0458	0.0573	0.0335	0.0416	0.0478	0.0608
3¾	0.0324	0.0396	0.0452	0.0568	0.0332	0.0410	0.0475	0.0598	0.0343	0.0429	0.0496	0.0636
4	0.0331	0.0407	0.0467	0.0591	0.0339	0.0423	0.0491	0.0623	0.0351	0.0443	0.0515	0.0663
4¼	0.0338	0.0419	0.0482	0.0614	0.0346	0.0435	0.0508	0.0648	0.0359	0.0457	0.0533	0.0691
4½	0.0345	0.0430	0.0498	0.0637	0.0354	0.0448	0.0525	0.0673	0.0367	0.0471	0.0551	0.0718
4¾	0.0351	0.0442	0.0513	0.0660	0.0361	0.0460	0.0542	0.0698	0.0375	0.0484	0.0569	0.0746
5	0.0358	0.0453	0.0528	0.0683	0.0368	0.0473	0.0558	0.0723	0.0383	0.0498	0.0588	0.0773
5½	0.0371	0.0476	0.0559	0.0729	0.0383	0.0498	0.0592	0.0773	0.0399	0.0526	0.0624	0.0828
6	0.0385	0.0499	0.0589	0.0775	0.0397	0.0523	0.0625	0.0823	0.0415	0.0553	0.0661	0.0883

These time values include time for put on and remove sleeve, put tool in tail stock and remove, tail-stock travel, tighten and loosen tail stock, change speed, start and stop machine, and lubricating time.

TABLE VII.—DRILLING, BORING, AND REAMING

Depth of hole, inches	Size of hole															
	¾ in.				1 in.				1¼ in.				1½ in.			
	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
½	0.0799	0.0810	0.0810	0.0816	0.0804	0.0816	0.0818	0.0831	0.0808	0.0823	0.0826	0.0859	0.0813	0.0831	0.0837	0.0891
¾	0.0822	0.0837	0.0838	0.0845	0.0827	0.0843	0.0847	0.0865	0.0831	0.0850	0.0857	0.0901	0.0836	0.0859	0.0870	0.0939
1	0.0848	0.0865	0.0867	0.0876	0.0853	0.0871	0.0877	0.0900	0.0857	0.0879	0.0888	0.0943	0.0862	0.0889	0.0904	0.0989
1¼	0.0871	0.0893	0.0895	0.0907	0.0876	0.0899	0.0906	0.0935	0.0880	0.0908	0.0919	0.0986	0.0885	0.0919	0.0937	0.1039
1½	0.0896	0.0921	0.0923	0.0938	0.0901	0.0928	0.0936	0.9970	0.0905	0.0938	0.0950	0.1028	0.0910	0.0950	0.0970	0.1089
1¾	0.0915	0.0945	0.0947	0.0963	0.0920	0.0951	0.0960	0.0999	0.0924	0.0961	0.0976	0.1065	0.0929	0.0974	0.0998	0.1132
2	0.0936	0.0968	0.0970	0.0988	0.0941	0.0974	0.0984	0.1028	0.0945	0.0985	0.1001	0.1101	0.0950	0.0999	0.1026	0.1176
2¼	0.0955	0.0991	0.0993	0.1013	0.0960	0.0997	0.1008	0.1057	0.0964	0.1009	0.1027	0.1138	0.0969	0.1024	0.1054	0.1220
2½	0.0976	0.1014	0.1016	0.1038	0.0981	0.1021	0.1033	0.1086	0.0985	0.1034	0.1053	0.1174	0.0990	0.1050	0.1082	0.1264
2¾	0.0995	0.1037	0.1039	0.1062	0.1000	0.1044	0.1057	0.1115	0.1004	0.1057	0.1079	0.1211	0.1009	0.1074	0.1110	0.1307
3	0.1016	0.1061	0.1063	0.1088	0.1021	0.1067	0.1081	0.1144	0.1025	0.1081	0.1104	0.1247	0.1030	0.1099	0.1138	0.1351
3¼	0.1035	0.1084	0.1086	0.1113	0.1040	0.1090	0.1105	0.1173	0.1044	0.1105	0.1130	0.1284	0.1049	0.1124	0.1165	0.1395
3½	0.1056	0.1107	0.1109	0.1138	0.1061	0.1114	0.1130	0.1202	0.1065	0.1130	0.1156	0.1320	0.1070	0.1150	0.1194	0.1439
3¾	0.1075	0.1130	0.1132	0.1162	0.1080	0.1137	0.1154	0.1231	0.1084	0.1153	0.1182	0.1357	0.1089	0.1174	0.1221	0.1482
4	0.1096	0.1154	0.1156	0.1188	0.1101	0.1160	0.1178	0.1260	0.1105	0.1177	0.1207	0.1393	0.1110	0.1199	0.1249	0.1526
4¼	0.1115	0.1177	0.1179	0.1213	0.1120	0.1183	0.1202	0.1289	0.1124	0.1201	0.1233	0.1430	0.1129	0.1224	0.1277	0.1570
4½	0.1136	0.1200	0.1202	0.1238	0.1141	0.1207	0.1227	0.1318	0.1145	0.1226	0.1259	0.1466	0.1150	0.1250	0.1306	0.1614
4¾	0.1155	0.1223	0.1225	0.1262	0.1160	0.1230	0.1251	0.1347	0.1164	0.1249	0.1285	0.1503	0.1169	0.1274	0.1333	0.1657
5	0.1176	0.1247	0.1249	0.1288	0.1181	0.1253	0.1275	0.1376	0.1185	0.1273	0.1310	0.1539	0.1190	0.1299	0.1361	0.1701
5½	0.1216	0.1293	0.1295	0.1337	0.1221	0.1299	0.1323	0.1434	0.1225	0.1321	0.1361	0.1612	0.1230	0.1348	0.1417	0.1789
6	0.1256	0.1340	0.1342	0.1388	0.1261	0.1346	0.1372	0.1492	0.1265	0.1369	0.1413	0.1685	0.1270	0.1399	0.1473	0.1876

These time values include time for drilling (including drilling constants), boring (including boring constants), and reaming (including reaming constants).

TABLE VII.—DRILLING, BORING, AND REAMING.—(*Continued*)

Depth of hole, inches	Size of hole											
	1¾ in.				2 in.				2¼ in.			
	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
½	0.0830	0.0838	0.0859	0.0925	0.0837	0.0853	0.0881	0.0964	0.0843	0.0874	0.0910	0.1007
¾	0.0856	0.0868	0.0897	0.0983	0.0864	0.0886	0.0923	0.1030	0.0871	0.0910	0.0956	0.1082
1	0.0884	0.0899	0.0935	0.1041	0.0892	0.0920	0.0966	0.1097	0.0900	0.0948	0.1004	0.1157
1¼	0.0911	0.0930	0.0973	0.1099	0.0919	0.0954	0.1008	0.1162	0.0928	0.0985	0.1052	0.1231
1½	0.0938	0.0961	0.1011	0.1156	0.0947	0.0988	0.1050	0.1228	0.0956	0.1024	0.1101	0.1306
1¾	0.0961	0.0988	0.1044	0.1207	0.0971	0.1017	0.1087	0.1286	0.0981	0.1056	0.1142	0.1372
2	0.0984	0.1014	0.1076	0.1258	0.0994	0.1046	0.1124	0.1345	0.1005	0.1089	0.1184	0.1438
2¼	0.1007	0.1040	0.1109	0.1309	0.1017	0.1075	0.1161	0.1403	0.1029	0.1121	0.1226	0.1504
2½	0.1030	0.1066	0.1142	0.1360	0.1041	0.1104	0.1198	0.1461	0.1053	0.1155	0.1269	0.1570
2¾	0.1052	0.1092	0.1175	0.1411	0.1064	0.1133	0.1235	0.1519	0.1077	0.1187	0.1310	0.1636
3	0.1076	0.1119	0.1207	0.1462	0.1088	0.1162	0.1272	0.1578	0.1102	0.1220	0.1352	0.1702
3¼	0.1099	0.1145	0.1240	0.1513	0.1111	0.1191	0.1309	0.1636	0.1126	0.1252	0.1394	0.1768
3½	0.1123	0.1172	0.1273	0.1564	0.1135	0.1220	0.1346	0.1694	0.1150	0.1286	0.1437	0.1834
3¾	0.1144	0.1197	0.1306	0.1615	0.1158	0.1249	0.1383	0.1752	0.1174	0.1318	0.1478	0.1900
4	0.1167	0.1223	0.1338	0.1666	0.1181	0.1278	0.1420	0.1811	0.1198	0.1351	0.1520	0.1966
4¼	0.1191	0.1250	0.1371	0.1717	0.1205	0.1307	0.1457	0.1869	0.1223	0.1383	0.1562	0.2032
4½	0.1215	0.1277	0.1404	0.1768	0.1229	0.1336	0.1494	0.1927	0.1247	0.1417	0.1605	0.2098
4¾	0.1237	0.1303	0.1437	0.1819	0.1252	0.1365	0.1531	0.1985	0.1271	0.1449	0.1646	0.2164
5	0.1259	0.1328	0.1469	0.1870	0.1275	0.1394	0.1568	0.2044	0.1295	0.1482	0.1688	0.2230
5½	0.1306	0.1381	0.1535	0.1972	0.1323	0.1452	0.1642	0.2160	0.1344	0.1548	0.1773	0.2362
6	0.1351	0.1433	0.1600	0.2074	0.1369	0.1510	0.1716	0.2277	0.1392	0.1613	0.1856	0.2494

These time values include time for drilling (including drilling constants), boring (including boring constants), and reaming (including reaming constants).

TABLE VII.—DRILLING, BORING, AND REAMING.—(*Continued*)

Depth of hole, inches	Size of hole											
	2½ in.				2¾ in.				3 in.			
	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
½	0.0851	0.0895	0.0938	0.1052	0.0858	0.0919	0.0968	0.1099	0.0873	0.0945	0.1008	0.1151
¾	0.087[illegible]	0.0936	0.0990	0.1135	0.0887	0.0963	0.1026	0.1190	0.0905	0.0993	0.1061	0.1251
1	0.0909	0.0977	0.1043	0.1217	0.0918	0.1009	0.1084	0.1280	0.0938	0.1043	0.1126	0.1349
1¼	0.0938	0.1019	0.1096	0.1300	0.0947	0.1053	0.1142	0.1371	0.0970	0.1093	0.1189	0.1449
1½	0.0967	0.1060	0.1150	0.1383	0.0978	0.1100	0.1202	0.1462	0.1002	0.1143	0.1259	0.1547
1¾	0.0992	0.1097	0.1196	0.1456	0.1003	0.1139	0.1253	0.1542	0.1030	0.1186	0.1314	0.1635
2	0.1017	0.1133	0.1242	0.1529	0.1029	0.1180	0.1304	0.1622	0.1058	0.1230	0.1371	0.1722
2¼	0.1042	0.1170	0.1289	0.1602	0.1054	0.1219	0.1355	0.1702	0.1086	0.1274	0.1426	0.1810
2½	0.1067	0.1206	0.1336	0.1675	0.1081	0.1260	0.1407	0.1782	0.1114	0.1318	0.1482	0.1897
2¾	0.1091	0.1243	0.1382	0.1748	0.1106	0.1299	0.1458	0.1862	0.1142	0.1361	0.1537	0.1985
3	0.1117	0.1279	0.1428	0.1821	0.1132	0.1340	0.1509	0.1942	0.1170	0.1405	0.1594	0.2072
3¼	0.1142	0.1316	0.1475	0.1894	0.1157	0.1379	0.1560	0.2022	0.1198	0.1449	0.1649	0.2160
3½	0.1167	0.1352	0.1522	0.1967	0.1180	0.1420	0.1612	0.2102	0.1226	0.1493	0.1705	0.2247
3¾	0.1191	0.1389	0.1568	0.2040	0.1209	0.1459	0.1663	0.2182	0.1254	0.1536	0.1760	0.2335
4	0.1216	0.1425	0.1614	0.2113	0.1235	0.1500	0.1714	0.2262	0.1282	0.1580	0.1817	0.2422
4¼	0.1242	0.1462	0.1661	0.2186	0.1260	0.1539	0.1765	0.2342	0.1310	0.1624	0.1872	0.2510
4½	0.1267	0.1498	0.1708	0.2259	0.1287	0.1580	0.1817	0.2422	0.1338	0.1668	0.1928	0.2597
4¾	0.1291	0.1535	0.1754	0.2332	0.1312	0.1619	0.1868	0.2502	0.1366	0.1711	0.1983	0.2685
5	0.1316	0.1571	0.1800	0.2405	0.1338	0.1660	0.1919	0.2582	0.1394	0.1755	0.2040	0.2772
5½	0.1366	0.1644	0.1893	0.2551	0.1390	0.1740	0.2022	0.2742	0.1450	0.1843	0.2151	0.2947
6	0.1416	0.1717	0.1986	0.2697	0.1441	0.1820	0.2124	0.2902	0.1506	0.1930	0.2263	0.3122

These time values include time for drilling (including drilling constants), boring (including boring constants), and reaming (including reaming constants).

Table VIII.—U. S. Standard Threads

Number threads per inch	Group 1				Group 2				Group 3				Group 4			
	Class 1 and 4	Const.	Class 2 and 3	Const.	Class 1 and 4	Const.	Class 2 and 3	Const.	Class 1 and 4	Const.	Class 2 and 3	Const.	Class 1 and 4	Const.	Class 2 and 3	Const.
2	0.0045	0.1596	0.0048	0.1919	0.0054	0.1681	0.0057	0.2004	0.0074	0.1794	0.0078	0.2116	0.0121	0.1963	0.0126	0.2286
3	0.0045	0.1145	0.0050	0.1468	0.0054	0.1230	0.0059	0.1552	0.0074	0.1286	0.0080	0.1609	0.0121	0.1455	0.0130	0.1778
4	0.0045	0.0948	0.0051	0.1270	0.0054	0.0976	0.0060	0.1299	0.0074	0.1032	0.0082	0.1355	0.0121	0.1173	0.0132	0.1496
4½	0.0045	0.0863	0.0052	0.1186	0.0054	0.0891	0.0061	0.1242	0.0074	0.0948	0.0083	0.1270	0.0121	0.1061	0.0134	0.1383
5	0.0045	0.0807	0.0052	0.1129	0.0054	0.0835	0.0062	0.1158	0.0074	0.0891	0.0084	0.1214	0.0121	0.0976	0.0135	0.1299
6	0.0045	0.0722	0.0054	0.1045	0.0054	0.0750	0.0063	0.1073	0.0074	0.0779	0.0086	0.1101	0.0121	0.0863	0.0138	0.1186
7	0.0045	0.0666	0.0057	0.0988	0.0054	0.0694	0.0065	0.1017	0.0074	0.0722	0.0088	0.1045	0.0121	0.0779	0.0141	0.1101
8	0.0045	0.0609	0.0057	0.0932	0.0054	0.0638	0.0066	0.0960	0.0074	0.0666	0.0090	0.0988	0.0121	0.0722	0.0144	0.1045
9	0.0045	0.0581	0.0058	0.0904	0.0054	0.0581	0.0068	0.0904	0.0074	0.0609	0.0092	0.0932	0.0121	0.0666	0.0146	0.0988
10	0.0045	0.0553	0.0061	0.0876	0.0054	0.0553	0.0070	0.0876	0.0074	0.0581	0.0094	0.0904	0.0121	0.0638	0.0149	0.0960
11	0.0045	0.0525	0.0061	0.0847	0.0054	0.0525	0.0071	0.0847	0.0074	0.0553	0.0096	0.0876	0.0121	0.0609	0.0152	0.0932
12	0.0045	0.0497	0.0062	0.0819	0.0054	0.0525	0.0073	0.0847	0.0074	0.0525	0.0099	0.0847	0.0121	0.0581	0.0155	0.0904
13	0.0045	0.0468	0.0064	0.0791	0.0054	0.0497	0.0074	0.0819	0.0074	0.0525	0.0101	0.0847	0.0121	0.0553	0.0158	0.0876
14	0.0045	0.0468	0.0066	0.0791	0.0054	0.0468	0.0076	0.0791	0.0074	0.0497	0.0103	0.0819	0.0121	0.0525	0.0161	0.0847
15	0.0045	0.0440	0.0067	0.0763	0.0054	0.0468	0.0078	0.0791	0.0074	0.0468	0.0105	0.0791	0.0121	0.0525	0.0164	0.0847
16	0.0045	0.0440	0.0068	0.0763	0.0054	0.0440	0.0079	0.0763	0.0074	0.0468	0.0107	0.0791	0.0121	0.0497	0.0167	0.0819
18	0.0045	0.0412	0.0071	0.0735	0.0054	0.0440	0.0083	0.0763	0.0074	0.0440	0.0111	0.0763	0.0121	0.0468	0.0173	0.0791
20	0.0045	0.0412	0.0074	0.0735	0.0054	0.0412	0.0086	0.0735	0.0074	0.0440	0.0115	0.0763	0.0121	0.0468	0.0179	0.0791
Minimum diameter to be used	16- or 18-in. E.L.	1 in.			1 in.				¾ in.				½ in.			
	24-in. E.L.	1¼ in.			1 in.				¾ in.				¾ in.			

Total threading time = (length of cut) × diameter × constant + threading constant.

TABLE IX.—BORING, TURNING, OR FACING CHART

Group 1

Finished	Accuracy	Feet per minute	Strong					Medium					Weak				
			R. C.	F. C.	Rough feed	Finished feed	Constant	R. C.	F. C.	Rough feed	Finished feed	Constant	R. C.	F. C.	Rough feed	Finished feed	Constant
Rough	Std.	*R* 300	2	..	0.025	.....	0.0013	3	..	0.025	.....	0.0019	4	..	0.025	.....	0.0026
Finished	±0.010 to	*R* 300	2	..	0.025	.....	0.0023	3	..	0.025	.....	0.0030	4	..	0.025	.....	0.0036
	±0.003	*F* 380	..	1	.....	0.012	......	..	1	.....	0.012	......	..	1	.....	0.012	
Finished	±0.003 to	*H* 300	2	..	0.025	.....	0.0034	3	..	0.025	.....	0.0040	4	..	0.025	.....	0.0047
	±0.000	*F* 380	..	2	.....	0.012	......	..	2	.....	0.012	......	..	2	.....	0.012	

One rough cut, 0.0006.
One finished cut, 0.0011.

Group 2

Finished	Accuracy	Feet per minute	Strong					Medium					Weak				
			R. C.	F. C.	Rough feed	Finished feed	Constant	R. C.	F. C.	Rough feed	Finished feed	Constant	R. C.	F. C.	Rough feed	Finished feed	Constant
Rough	Std.	*R* 200	2	..	0.025	.....	0.0019	3	..	0.025	.....	0.0029	4	..	0.025	.....	0.0038
Finished	±0.010 to	*R* 200	2	..	0.025	.....	0.0034	3	..	0.025	.....	0.0043	4	..	0.025	.....	0.0053
	±0.003	*F* 280	..	1	.....	0.012	......	..	1	.....	0.012	......	..	1	.....	0.012	
Finished	±0.003 to	*R* 200	2	..	0.025	.....	0.0048	3	..	0.025	.....	0.0058	4	..	0.025	.....	0.0067
	±0.000	*F* 280	..	2	.....	0.012	......	..	2	.....	0.012	......	..	2	.....	0.012	

One rough cut, 0.0010.
One finished cut, 0.0014.

TABLE IX.—BORING, TURNING, OR FACING CHART.—(*Continued*)

Group 3

Finished	Accuracy	Feet per minute	Strong					Medium					Weak				
			R. C.	F. C.	Rough feed	Finished feed	Constant	R. C.	F. C.	Rough feed	Finished feed	Constant	R. C.	F. C.	Rough feed	Finished feed	Constant
Rough	Std.	*R* 150	2	..	0.025	.....	0.0026	3	..	0.025	.....	0.0039	4	..	0.025	.....	0.0052
Finished	±0.010 to	*R* 150	2	..	0.025	.....	0.0044	3	..	0.025	.....	0.0059	4	..	0.025	.....	0.0070
	±0.003	*F* 220	..	1	.....	0.012	......	..	1	.....	0.012	......	..	1	.....	0.012	
Finished	±0.003 to	*R* 150	2	..	0.025	.....	0.0062	3	..	0.025	.....	0.0077	4	..	0.025	.....	0.0088
	±0.000	*F* 220	..	2	.....	0.012	......	..	2	.....	0.012	......	..	2	.....	0.012	

One rough cut, 0.0013.
One finished cut, 0.0018.

Group 4

Finished	Accuracy	Feet per minute	R. C.	F. C.	Rough feed	Finished feed	Constant	R. C.	F. C.	Rough feed	Finished feed	Constant	R. C.	F. C.	Rough feed	Finished feed	Constant
Rough	Std.	*R* 100	2	..	0.025	.....	0.0039	3	..	0.025	.....	0.0058	4	..	0.025	.....	0.0077
Finished	±0.010 to	*R* 100	2	..	0.025	.....	0.0064	3	..	0.025	.....	0.0083	4	..	0.025	.....	0.0102
	±0.003	*F* 160	..	1	.....	0.012	......	..	1	.....	0.012	......	..	1	.....	0.012	
Finished	±0.003 to	*R* 100	2	..	0.025	.....	0.0089	3	..	0.025	.....	0.0108	4	..	0.025	.....	0.0127
	±0.000	*F* 160	..	2	.....	0.012	......	..	2	.....	0.012	......	..	2	.....	0.012	

One rough cut, 0.0019.
One finished cut, 0.0025.

TABLE X.—GROOVING AND PARTING CHART

	Grooving								Parting		
Size of groove	Up to and including ¼ in.		From ¼ to and including ½ in.		From ½ to and including ¾ in.		From ¾ to and including 1 in.				
Accuracy	Std. to ±0.003	±0.003 to ±0.000	Std. to ±0.003	±0.003 to ±0.000	Std. to ±0.003	±0.003 to ±0.000	Std. to ±0.003	±0.003 to ±0.000	.....	Feet per minute	Feed
Group 1	1 cut	2 cuts	2 cuts	3 cuts	3 cuts	4 cuts	4 cuts	5 cuts	1 cut	120	0.0107
Group 2	1 cut	2 cuts	2 cuts	3 cuts	3 cuts	4 cuts	4 cuts	5 cuts	1 cut	90	0.0107
Group 3	1 cut	2 cuts	2 cuts	3 cuts	3 cuts	4 cuts	4 cuts	5 cuts	1 cut	70	0.0107
Group 4	1 cut	2 cuts	2 cuts	3 cuts	3 cuts	4 cuts	4 cuts	5 cuts	1 cut	50	0.0107

TABLE XI.—DRILLING CHART

	Group 1. 300 feet per minute			Group 2. 200 feet per minute			Group 3. 160 feet per minute			Group 4. 100 feet per minute			
Drill size	R.p.m.	Feed	Time per inch	R.p.m.	Feed	Time per inch	R.p.m.	Feed	Time per inch	R.p.m.	Feed	Time per inch	Lead of drill
0.75	420	0.007	0.0062	420	0.006	0.0073	420	0.006	0.0073	420	0.006	0.0073	0.225
1.0	420	0.007	0.0062	420	0.006	0.0073	420	0.006	0.0073	382	0.006	0.0080	0.300
1.25	420	0.007	0.0062	420	0.006	0.0073	420	0.006	0.0073	305	0.006	0.0100	0.375
1.5	420	0.007	0.0062	420	0.006	0.0073	407	0.006	0.0075	254	0.006	0.0120	0.450
1.75	420	0.006	0.0073	420	0.006	0.0073	349	0.006	0.0088	218	0.006	0.0140	0.525
2.0	420	0.006	0.0073	382	0.006	0.0080	305	0.006	0.0100	191	0.006	0.0160	0.600
2.25	420	0.006	0.0073	339	0.006	0.0090	271	0.006	0.0113	170	0.006	0.0180	0.675
2.5	420	0.006	0.0073	305	0.006	0.0100	244	0.006	0.0125	152	0.006	0.0200	0.750
2.75	416	0.006	0.0074	278	0.006	0.0110	222	0.006	0.0138	139	0.006	0.0220	0.825
3.0	382	0.006	0.0080	254	0.006	0.0120	204	0.006	0.0150	127	0.006	0.0240	0.900

TABLE XII.—REAMING CHART

Reamer size	Group 1. 180 feet per minute			Group 2. 120 feet per minute			Group 3. 90 feet per minute			Group 4. 60 feet per minute		
	R.p.m.	Feed	Time per inch	R.p.m.	Feed	Time per inch	R.p.m.	Feed	Time per inch	R.p.m.	Feed	Time per inch
0.75	420	0.025	0.0018	420	0.022	0.0020	420	0.022	0.0020	305	0.022	0.0027
1.0	420	0.025	0.0018	420	0.022	0.0020	344	0.022	0.0024	229	0.022	0.0036
1.25	420	0.025	0.0018	366	0.022	0.0023	274	0.022	0.0030	183	0.022	0.0046
1.5	420	0.025	0.0018	305	0.022	0.0027	228	0.022	0.0037	153	0.022	0.0055
1.75	392	0.025	0.0019	262	0.022	0.0032	196	0.022	0.0043	131	0.022	0.0064
2.0	344	0.025	0.0021	229	0.022	0.0036	175	0.022	0.0048	114	0.022	0.0073
2.25	305	0.025	0.0024	204	0.022	0.0041	152	0.022	0.0055	102	0.022	0.0084
2.5	274	0.025	0.0027	183	0.022	0.0046	137	0.022	0.0061	91	0.022	0.0092
2.75	250	0.025	0.0029	167	0.022	0.0050	125	0.022	0.0067	83	0.022	0.0100
3.0	229	0.025	0.0032	153	0.022	0.0055	114	0.022	0.0073	76	0.022	0.0110

$$\text{Time per inch} = \frac{0.0167}{\text{R.p.m.} \times \text{feed}} \times 110 \text{ per cent.}$$

TABLE XIII.—U. S. STANDARD THREADS

		Group 1. 100 feet per minute		Group 2. 90 feet per minute		Group 3. 70 feet per minute		Group 4. 50 feet per minute	
Feed per cut, inches		0.008		0.0075		0.007		0.006	
No. of threads per in.	Single depth of one side	No. of cuts		No. of cuts		No. of cuts		No. of cuts	
		Class		Class		Class		Class	
		1 or 4	2 or 3	1 or 4	2 or 3	1 or 4	2 or 3	1 or 4	2 or 3
2	0.375	46.90	49.90	50.00	53.00	53.60	56.60	62.53	65.53
3	0.2505	31.34	34.90	33.44	36.44	35.80	38.80	41.80	44.80
4	0.1888	23.50	26.50	25.08	28.08	26.84	29.84	31.35	34.35
4½	0.1668	20.83	23.83	22.22	25.22	23.80	26.80	27.79	30.79
5	0.1498	18.74	21.74	19.98	22.98	21.40	24.40	24.95	27.95
6	0.125	15.62	18.62	16.67	19.67	17.86	20.86	20.83	23.83
7	0.1072	13.82	16.82	14.31	17.31	15.33	18.33	17.89	20.89
8	0.0938	11.72	14.72	12.50	15.50	13.39	16.39	15.62	18.62
9	0.0832	10.40	13.40	11.09	14.09	11.88	14.88	13.86	16.86
10	0.0749	9.36	12.36	9.98	12.98	10.69	13.69	12.48	15.48
11	0.0682	8.53	11.53	9.09	12.09	9.74	12.74	11.37	14.37
12	0.0624	7.79	10.79	8.32	11.32	8.91	11.91	10.40	13.40
13	0.0576	7.20	10.20	7.68	10.68	8.23	11.23	9.60	12.60
14	0.0536	6.70	9.70	7.15	10.15	7.66	10.66	8.94	11.94
15	0.0501	6.27	9.27	6.68	9.68	7.16	10.16	8.36	11.36
16	0.0468	5.85	8.85	6.24	9.24	6.69	9.69	7.80	10.80
18	0.0419	5.24	8.24	5.58	8.58	5.98	8.98	6.98	9.98
20	0.0375	4.69	7.69	5.00	8.00	5.36	8.36	6.25	9.25

$$\text{Number of cuts per thread} = \frac{\text{depth of one side of thread}}{\text{feed per cut in inches}}.$$

Note.—Depth of thread has been calculated on 30-degree angle. Three extra cuts are allowed for Class 2 or 3 threads.

CHAPTER XXXV

FORMULA FOR ALLOY CASTINGS MOLDED ON BENCH

The formula example given in this chapter is for the brass foundry operation of bench molding. In this particular case, the work is of an extremely varied nature. The number of patterns molded in a flask varies from one to seven. Because of this great variation, it was believed, for a long time, to be out of the realm of incentive systems. At length, however, the idea was conceived of allowing a certain amount of time for each flask, regardless of the number of patterns contained therein. The foreman in charge was to see that each molder utilized the flask space to the best advantage, and the moveman or checker was to approve the number of molds made. The thought was that while there would be many inconsistencies over a pay period of 2 weeks, the average would be about right. As a matter of fact, the bonus earned was fairly consistent if the nature of the work remained the same from pay to pay, but the men were not satisfied, and it was difficult to make an equitable distribution of the costs. In slack times, there was a tendency not to crowd as many patterns into a flask as in good times, thus making the work on hand last longer. In general, the plan was found to be unsatisfactory; so the work was time studied with a view to making a formula. The time spent has been more than justified by increased production with consequent reduced costs to the company and by the satisfaction of the workers in having earnings directly proportional to effort. The operators now know the amount of time they are allowed for each casting, and the foreman is relieved from checking to see that the flask space is being used to the best advantage. The costing of the operation is definite and accurate. This example should clearly demonstrate the possibilities of formula application to foundry work.

Formula O-4 No. 7.
Nov. 1, 1924.

Part:
Alloy castings molded on bench.
Operation:
Mold.
Work Station:
Bench.
Allowed Time:
First-piece Time.
Simple: $0.0500 + 0.075D + 1.10$ (additional-piece time).
Medium: $0.1000 + 0.00188C' + 0.075D + 1.10$ (additional-piece time).
Complex: $0.1750 + 0.0077C' + 1.10$ (additional-piece time).
Additional-piece Time.
Simple: $\frac{0.2959}{A} + 0.00234C + 0.0207P + NB + R.$
Medium: $\frac{0.3013}{A} + 0.00384C + 0.0434P + NB + k.$
Complex: $\left(\frac{0.3936}{A} + 0.0129C + NB + R'\right) 1.10.$
Add 0.019 to above formulas for each frame necessary,
where A = see Table 1 or 1A.
B = see Table 2.
C = total length of parting line in inches.
C' = total length of parting line in match in inches.
D = use when cores are required.
N = number of cores.
P = number of parts per pattern.
R = 0.0150 when reinforcing is necessary.
R' = 0.0500 when reinforcing is necessary.

TABLE 1.—VALUES OF A FOR ALL CASTINGS BUT COPPER BLOCKS

A = 1 when greatest pattern area falls between 50 square inches and up.
A = 2 when greatest pattern area falls between 25 to 50 square inches.
A = 3 when greatest pattern area falls between 15 to 25 square inches.
A = 4 when greatest pattern area falls between 11 to 15 square inches.
A = 5 when greatest pattern area falls between 9 to 11 square inches.
A = 6 when greatest pattern area falls between 6 to 9 square inches.
A = 7 when greatest pattern area falls up to 6 square inches.

TABLE 1A.—VALUES OF A FOR COPPER BLOCKS

A = 1 for areas of 25 square inches and up.
A = 2 for areas of 15 to 25 square inches.
A = 3 for areas of 11 to 15 square inches.

TABLE 2.—CORES

Class	Decimal Hours
* A	0.005
B	0.014
C	0.026
D	0.062

* A-D. See Core Classification.

Application:

This formula applies to all molding of alloy castings done on the bench in flasks up to 18 by 14 by 8 inches with or without frames as done in *O*-4 at the present time.

Analysis:

Tools and equipment needed are bottom boards, molding boards, flasks, riddle, shovel, molding sand, patterns, parting sand, peen and rammers, strike bar, venting pins, core glue, reinforcing nails, water and brushes, gater, slicks, drawing and rapping tools, sprue and riser cutters, cores, bellows, compressed air, graphite, weights, gate patterns, frames, match, file, and iron hook for shake out.

Jobs are put in work by production clerk by sending tag to pattern stores. Pattern keeper draws patterns and core boxes and delivers them. Group leader assigns jobs to each molder. Each molder gets his own cores.

Sand is brought to molders by laborer when needed. Laborer removes finished castings to band saws. Each molder pours and shakes out his own flasks and mixes his own sand.

Ten per cent of additional-piece time is allowed in first-piece time to cover time spent by molder in receiving instructions and the time spent getting equipment ready and determining the best way to do the job.

Two sprue holes are allowed per mold. Table of *A* takes care of the number of different patterns sharing mold constant. In order to make the most standard time, the molder must have this flask as full as possible.

Frames are used whenever the pattern is so large that the regular cope or drag does not leave a deep enough section of sand. The sand may be fairly thin if casting section is small and cools rapidly, but for casting sections of say 15 square inches, at least 3 inches of sand should be between the metal and the bottom board in the drag. In the cope, the sand must be high enough to provide sufficient head in the risers to feed in metal to take care of cooling shrinkage. Here again, the height necessary depends on the size of the casting. In general, the larger the part of the casting in the cope, the higher must be the riser. Alloys 1 and 6 have greater shrinkage than the other alloys commonly used and for this reason must be provided with more generous risers.

Reinforcing with nails is necessary when patterns have narrow sections, pockets, etc., or are very straight. Holes in patterns and weak edges are also reinforced.

No scrapped castings are to receive a standard-time value. They are considered to be made on the molder's own time. For this reason and to care for fatigue and the more than usual unavoidable delays to which a molder is subjected, an allowance of 30 per cent is given.

It is recognized that it takes longer to pour copper than the other alloys because it is necessary to test the condition of each furnace charge and to cover over sprue and riser holes with dry sand and also because, in the majority of cases, more than two sprues and risers are needed. On the other hand, no copper jobs have thin intricate sections and there is not the amount of patching and dressing necessary that there is in other more complicated work. At the same time, copper jobs are considered to fall into the simple

or the medium classification, according to the nature of the parting line, although the time allowed for patching and dressing is greater than is actually necessary. These two conditions offset each other so that the total time per casting will be given by the same formula that is used in other cases.

By copper blocks is meant heavy solid "chunks" of copper. Due to the great cooling shrinkage of copper, it is necessary to have large risers on top of each "chunk." This does not leave as much room for other patterns as there is when these risers are not used. The values of A given in the table for copper blocks are to be used whenever the casting has a large solid section. Many of these blocks must be made in the cope to insure a smooth surface, and in these cases care must be taken to allow time for adding a frame.

Plain cylindrical castings taking a plain cylindrical core in the center are made from a split pattern. In this case, the total length of the parting line is taken to be the length of the parting line of one-half of the pattern only. This is because these are very simple patterns and require very little or no patching. Using the actual total length of the parting line would give a patching time much greater than that actually required.

Chills are to be considered as Class C cores. Care should be used in determining values of A when chills are used to allow the greater area as determined with the chills in place.

Only castings which appear on the shipping report of the brass foundry will be paid for. This eliminates the problem of keeping a record of scrap. First-piece time will be allowed every time a job is marked as finished on the shipping report.

Complex jobs are largely carbon brush holders. Here the parting line is very irregular and the draw hard. An additional 10 per cent is allowed on all these jobs to care for excess patching which may be necessary. Most of these patterns are old and warped, making the draw additionally difficult. Except where a special match board is used, it will be considered that only one is done in a flask. Only a very skilled molder can put two in a flask and then only after he has worked the job for some time. When a match board is used, two patterns may be easily made in one flask. In this case, preparation time is not allowed on the first piece. If only one pattern is ordered for a job with two patterns on one match board, only one pattern will be used. The worker should not be penalized for this, and a special time value should be set for this condition. All complex patterns are considered to be made in one piece.

Pattern Classification:

Simple: Simple edges, not numerous, thick sections, parting line in one plane.

Medium: Several edges, ribs, etc., thin sections or pockets not deep but requiring reinforcing, parting line not in one plane.

Complex: Many edges, ribs, projections, hollows, etc., thin sections, deep and narrow sections requiring reinforcing, parting line very irregular, complicated cope making a difficult draw. Most brush holders fall in this class

Core Classification:

A: Simple cylindrical cores and other small cores where no filing or fitting is necessary.

B: Cores having few, if any, projections, taking a slight smoothing of the edges before placing.

C: Cores having projections, thin sections, etc., requiring venting and fitting into place.

D: Large and complicated cores, or cores which must be held in place by nails to prevent floating.

Procedure:

Place molding board or match, place patterns, place drag, shake on parting sand, fill riddle, riddle, peen around pattern with fingers, fill drag, peen, refill drag, ram, strike, turn, remove molding board or match, prepare drag for cope, place cope, lay in upper halves of patterns if any, reinforce if necessary, shake on parting sand, fill riddle, riddle, fill cope, peen, refill cope, ram, strike, vent, place molding board, draw cope, gate cope and drag, cut sprue hole and riser, moisten pattern edges, draw patterns, repair cope and drag, file and place cores if any, place drag on floor, stand cope on edge, finish sprue holes on top, place cope on drag, place on weight, prepare for next mold, pour, remove weight, shake out flask and stack, inspect and remove casting, wet and mix sand.

TIME STUDIES

Study Number	Date	Taken by
S-1	10–2–24	H. B. M.
S-2	10–2–24	"
S-3	10–3–24	"
S-4	10–3–24	"
S-5	10–3–24	"
S-6	10–3–24	"
S-7	10–6–24	"
S-8	10–6–24	"
S-9	10–7–24	"
S-10	10–9–24	"
S-11	10–10–24	"
S-12	10–13–24	"

Also miscellaneous short studies covering pouring, shake out, and first-piece time.

TABLE OF DETAIL VALUES

Symbol	Operation Description	Reference	Standard Time
A	Place match or molding board on bench	*S*-6	0.0020
B	Place drag	*S*-2-4	0.0032
C	Parting sand	*S*-1-6	0.0026
D	Fill riddle	*S*-10-11	0.0032
E	Riddle	*S*-5	0.0070
F	Fill drag (or cope)	*S*-2	0.0046
G	Peen	*S*-4-3	0.0092
H	Refill drag (or cope)	*S*-4	0.0040
I	Ram	*S*-2-10	0.0078
J	Strike	*S*-7	0.0044
K	Place bottom board	*S*-2-10-11	0.0042

TABLE OF DETAIL VALUES.—(*Continued*)

Symbol	Operation Description	Reference	Standard Time
L	Turn..........................	*S*-3-8	0.0026
M	Remove match..................	*S*-1-6	0.0034
N	Place cope....................	*S*-12	0.0057
O	Cut and finish sprue hole complete...	*S*-3	0.0178
P	Stand cope on edge and remove molding board	*S*-2	0.0034
Q	Place drag on floor...............	*S*-1	0.0044
R	Place cope on drag................	*S*-1-3-9	0.0062
S	Prepare for next..................	*S*-1	0.0027
T	Place on weight...................	*S*-2-8	0.0038
U	Place frame.......................	*S*-5-6	0.0022
V	Fill frame........................	*S*-5-6	0.0036
W	Gate complete.....................	*S*-12	0.0628
X	Peen with fingers..................	See Pattern Classification Table	
Y	Lay pattern in place...............	See Pattern Classification Table	
Z	Prepare drag......................	See Curves *C-C* lines	
A'	Reinforce........................	Simple and medium 0.0150 Complex 0.0500	
B'	Draw cope........................	See Pattern Classification Table	
C'	Repair cope......................	See Curves *C-C* lines	
D'	Repair drag......................	See Curves *C-C* lines	
E'	Get core and scrape...............	See Core Classification Table	
F'	Place cores......................	See Core Classification Table	
G'	Vent............................	See Core Classification Table	
H'	Moisten edges....................	See Curves *C-C* lines	
I'	Shellac core.....................	See Core Classification Table	
K'	Place upper pattern...............	See Pattern Classification Table	
L'	Draw upper part..................	See Pattern Classification Table	
As	Remove weight..................................		0.0036
Bs	Inspect and remove casting.........................		0.0096
Cs	Shake out and stack flask..........................		0.0122
Ds	Wet per flask..................................		0.0104
Es	Shovel per flask................................		0.0217
Af	Walk to pattern rack and return....................		0.0150
Bf	Select job.....................................		0.0200
Cf	Get cores from core room..........................		0.0750
Df	Return job to pattern rack.........................		0.0150

PATTERN CLASSIFICATION TABLE

Operation	Simple	Medium	Complex
Lay pattern in place........................	0.0040	0.0065	0.0065
Draw cope..............................	0.0040	0.0055	0.0170
Draw pattern (includes rap).................	0.0052	0.0109	0.0283
Vent..................................	......	......	0.0087
Finger peen (cope and drag).................	0.0025	0.0090	0.0188
Wait for help............................	......	0.0065	0.0130
Total..............................	0.0157	0.0384	0.0923

CORE CLASSIFICATION TABLE

Operation	A	B	C	D
File core	......	0.0079	0.0090	Selected
Place core	0.0050	0.0060	0.0081	from
Vent core seat	......	......	0.0091	totals
Total	0.0050	0.0139	0.0262	0.0625

Synthesis:

$B + 2C + 2D + 2E + 2F + 2G + 2H + 2I + 2J + 2K + L + N + 2O + P + Q + R + S + T + W = 0.0032 + 0.0052 + 0.0064 + 0.0140 + 0.0092 + 0.0184 + 0.0080 + 0.0156 + 0.0088 + 0.0084 + 0.0026 + 0.0057 + 0.0356 + 0.0034 + 0.0044 + 0.0062 + 0.0027 + 0.0038 + 0.0628 = 0.2244$ = constant per mold to make.

$As + Bs + Cs + Ds + Es = 0.0036 + 0.0096 + 0.0122 + 0.0104 + 0.0217 = 0.0575$ = constant per mold to shake out.

(Prepare to pour + 3 × pour + 2 × move + return to bench) ÷ 3 = $(0.0145 + 3 \times 0.0038 + 2 \times 0.0031 + 0.0096) \div 3 = 0.0140$ = constant per mold to pour.

$A + M = 0.0020 + 0.0034 = 0.0054$ + constant per match = constant per mold for medium patterns.

$0.2244 + 0.0575 + 0.0140 = 0.2959$ = constant per simple mold.

$0.2244 + 0.0575 + 0.0140 + 0.0054 = 0.3013$ = constant per medium mold.

$G + H + U + V = 0.0092 + 0.0040 + 0.0022 + 0.0036 = 0.0190$ = constant per frame.

$Af + Bf + Df = 0.0150 + 0.0200 + 0.0150 = 0.0500$ = constant for simple first piece.

$Af + Bf + Df + D + E + G + H + I + J + K + L + U + V = 0.0150 + 0.0200 + 0.0150 + 0.0032 + 0.0070 + 0.0092 + 0.0040 + 0.0078 + 0.0044 + 0.0042 + 0.0026 + 0.0022 + 0.0036 = 0.1000$ = constant for medium first piece.

$Af + Bf + Cf + Df + D + E + G + H + I + J + K + L + U + V = 0.0150 + 0.0200 + 0.0750 + 0.0150 + 0.0032 + 0.0070 + 0.0092 + 0.0040 + 0.0078 + 0.0044 + 0.0042 + 0.0026 + 0.0022 + 0.0036 = 0.1750$ = constant for complex first piece.

Inspection:

Castings are inspected to see that they are as nearly perfect as is consistent with foundry practice. Castings must be filled out in every part and have no sand holes, blow holes, or sections out of place due to washed sand or cores.

Payment:

Standard-time group plan.

Approved:

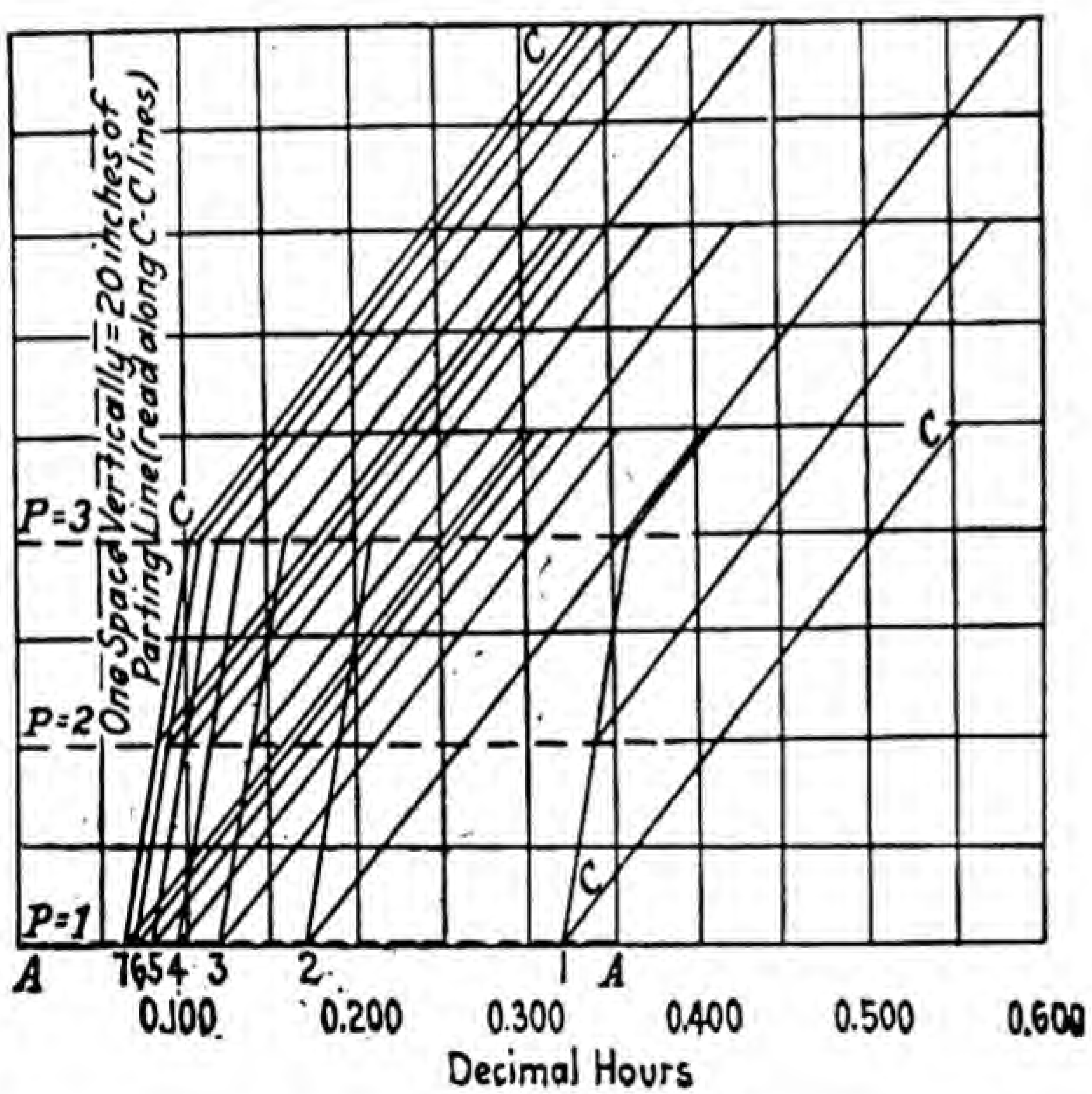
Time-study Supervisor   Time-study Department

Core Table	
Class	Dec. Hrs.
A	0.005
B	0.014
C	0.026
D	0.062

$$\text{Standard Time} = \frac{0.2959}{A} + 0.00234C + 0.0207P + NB + R$$

A—See Table of "A" below.
B—See Core Table.
C—Total length of parting line in inches.
N—Number of cores.
P—Number of parts of pattern.
R—0.0150 where reinforcing is necessary.

CURVE 1
Bench Molding—Simple Pattern
Simple Flask—up to 18″ × 14″ × 8″
Formula 0-4 #7 Nov. 15, 1924
Approved: *D. W. Milton*



Add 0.019 Hours per Frame.

Greatest Pattern Area	A
50 sq. in. and up.....	1
25 sq. in. to 50 sq. in.	2
15 sq. in. to 25 sq. in.	3
11 sq. in. to 15 sq. in.	4
9 sq. in. to 11 sq. in.	5
6 sq. in. to 9 sq. in.	6
Up to 6 sq. in........	7

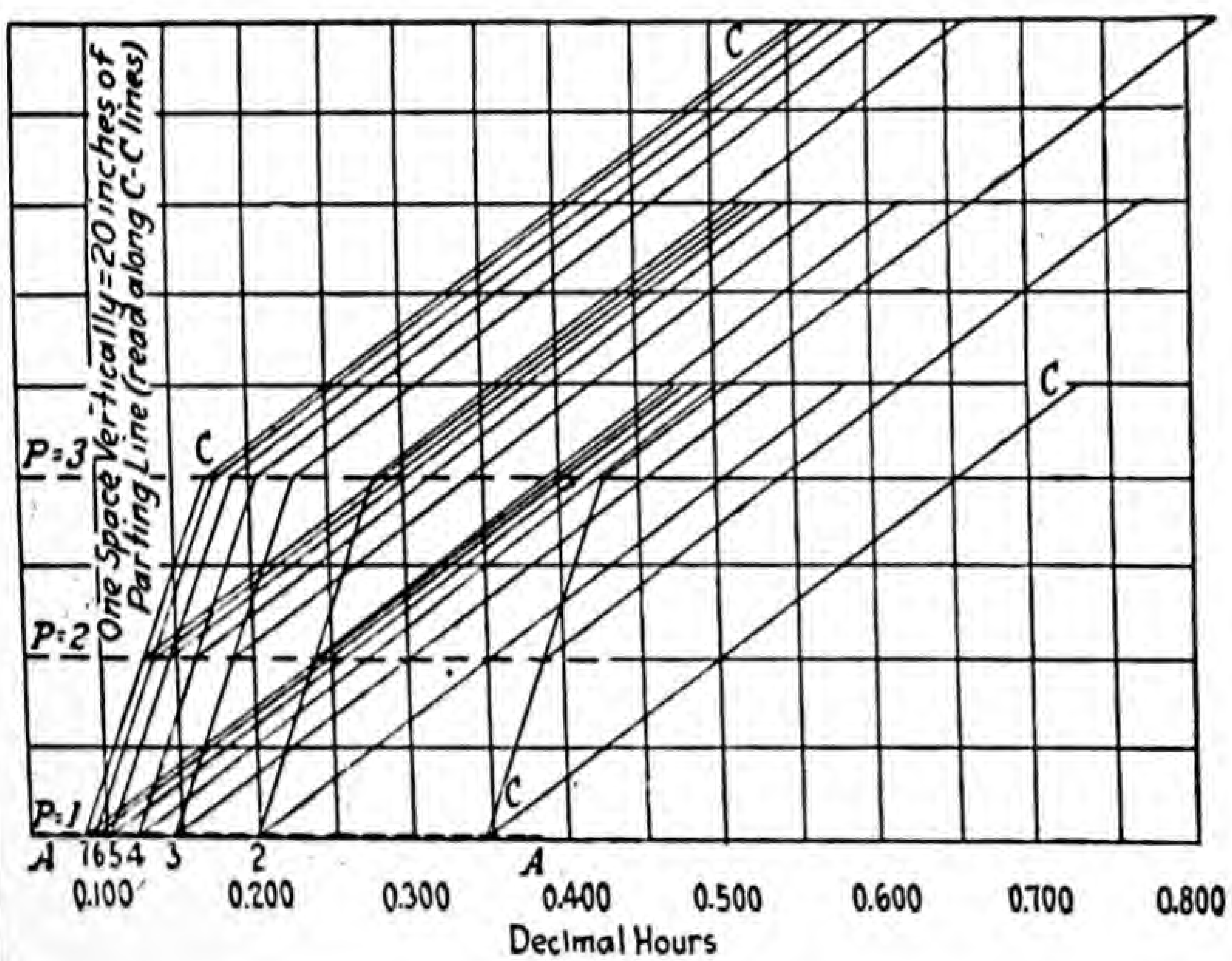
CURVE 1.

Core Table	
Class	Dec. Hrs.
A	0.005
B	0.014
C	0.026
D	0.062

$$\text{Standard Time} = \frac{0.3013}{A} + 0.00384C + 0.0434P + NB + R$$

A—See Table of "A" below.
B—See Core Table.
C—Total length of parting line in inches.
N—Number of cores.
P—Number of parts of pattern.
R—0.015 where reinforcing is necessary.

CURVE 2
Bench Molding—Medium Pattern
Simple Flask—up to 18″ × 14″ × 8″
Formula 0-4 #7 Nov. 15, 1924
Approved: *D. W. Milton*



Add 0.019 Hours per Frame

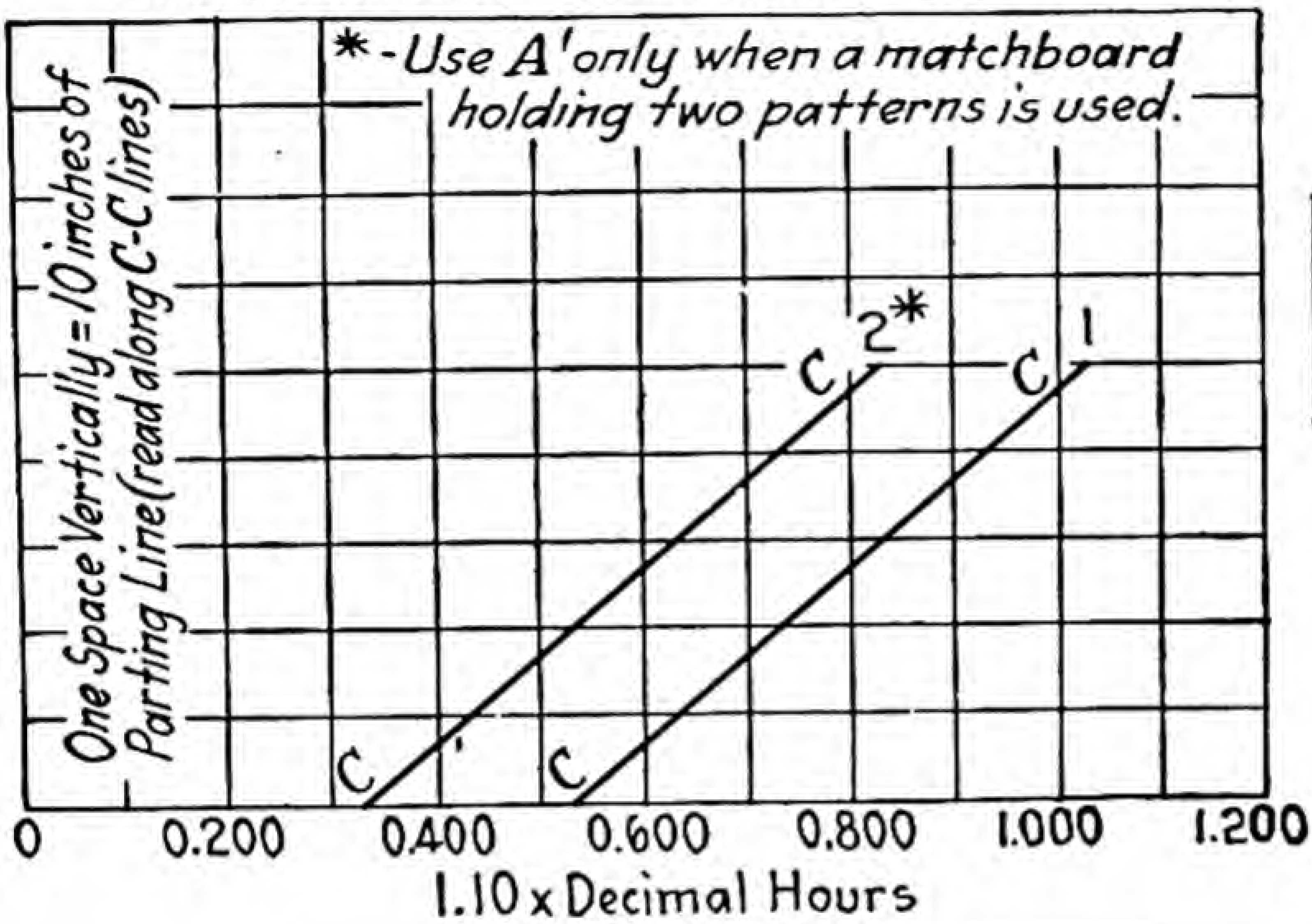
Greatest Pattern Area	A
50 sq. in. and up.....	1
25 sq. in. to 50 sq. in.	2
15 sq. in. to 25 sq. in.	3
11 sq. in. to 15 sq. in.	4
9 sq. in. to 6 sq. in.	5
6 sq. in. to 9 sq. in.	6
Up to 6 sq. in........	7

CURVE 2.

$$\text{Standard Time} = \left(\frac{0.3936}{A'} + 0.0129C + NB + R'\right) 1.10$$

A′—See write up.
B—See Core Table.
C—Total length of parting line in inches.
N—Number of cores.
R—Use when reinforcing is necessary = 0.0500
—for use with curve = $1.10 \times 0.0500 = 0.0550$

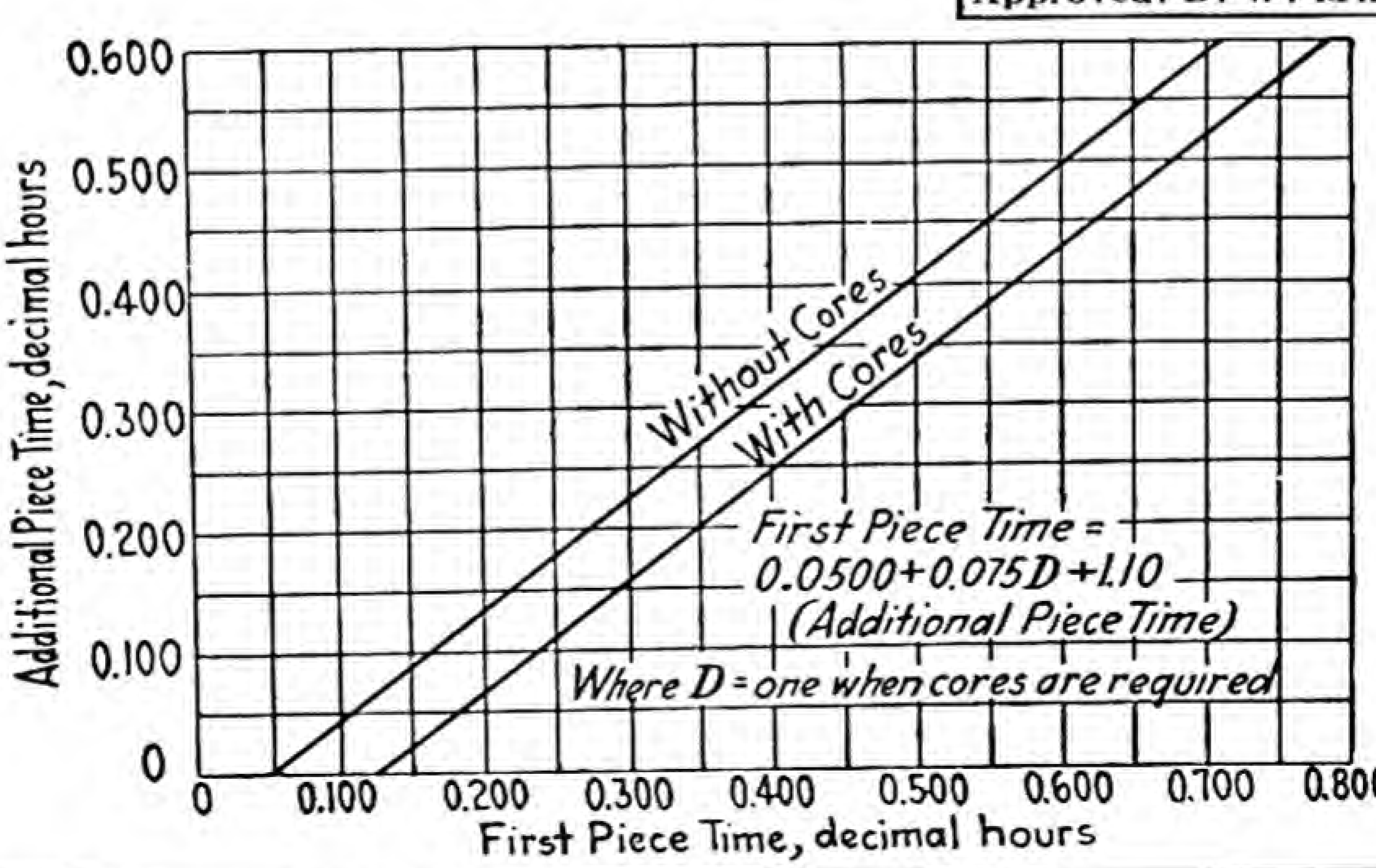
CURVE 3
Bench Molding—Complex Pattern
Simple Flask—up to 18″ × 14″ × 8″
Formula 0-4 #7 Nov. 15, 1924
Approved *D. W. Milton*



Core Table	
Class	Dec. Hrs.
A	0.005
B	0.015
C	0.028
D	0.068

CURVE 3.

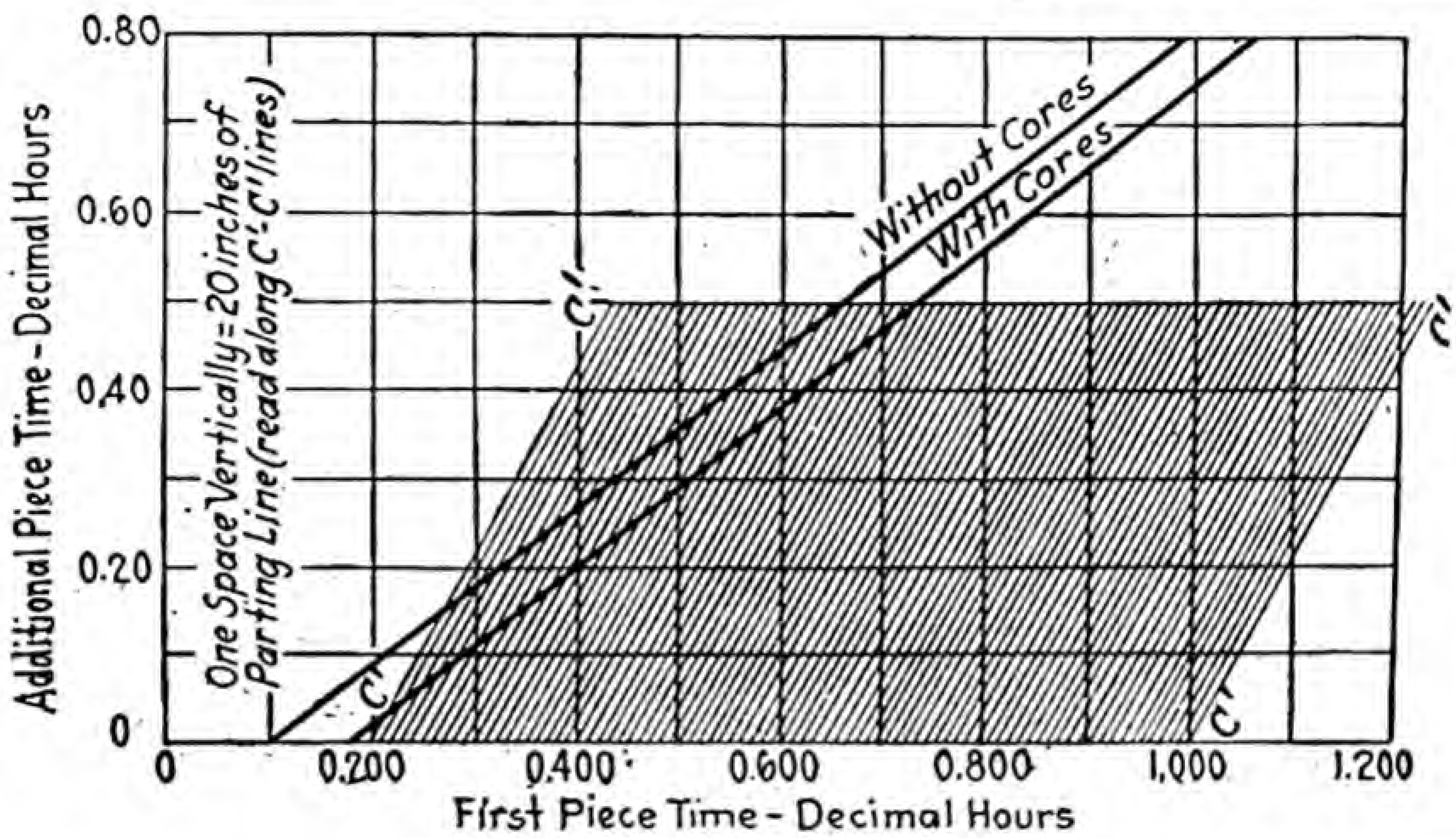
CURVE 4
Bench Molding—Simple Pattern
Simple Flask—up to 18″ × 14″ × 8″
Formula 0-4 #7 Nov. 15, 1924
Approved: *D. W. Milton*



CURVE 4.

First Piece Time = 0.100 + 0.00186C′ + 0.075D + 1.10 (Additional Piece Time)
C′ = Total length of parting line in match in inches
D = One when cores are required

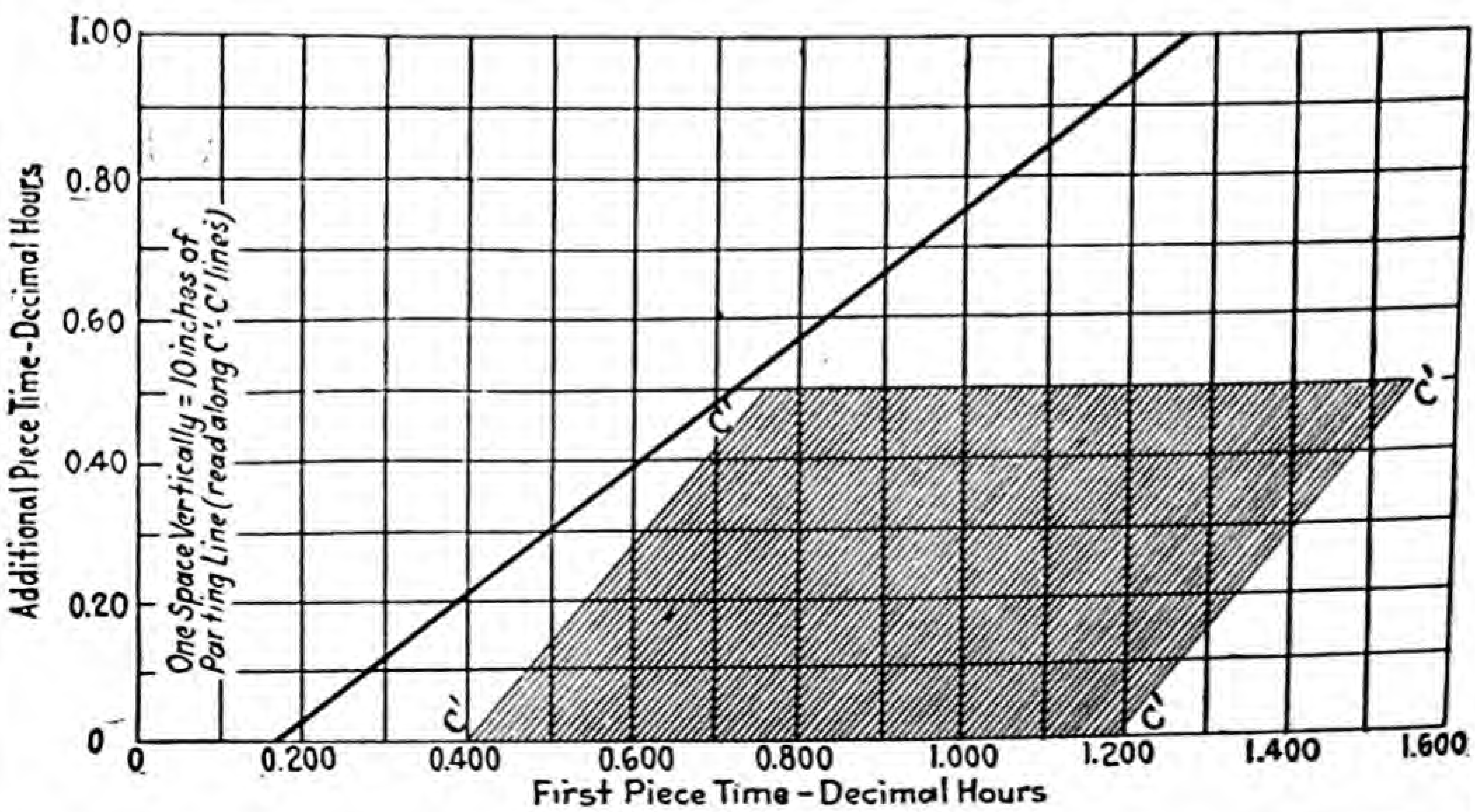
Curve 5
Bench Molding—Medium Pattern
Simple Flask—up to 18″ × 14″ × 8″
Formula 0-4 #7 Nov. 15, 1924
Approved: *D. W. Milton*



Curve 5.

First Piece Time = 0.1750 + 0.0077C′ + 1.10 (Additional Piece Time)
C′—Total length of parting line in match in inches

Curve 6
Bench Molding—Complex Patterns
Simple Flask—up to 18″ × 14″ × 8″
Formula 0-4 #7 Nov. 16, 1924
Approved: *D. W. Milton*



Curve 6.

INDEX

P

Q

R

S